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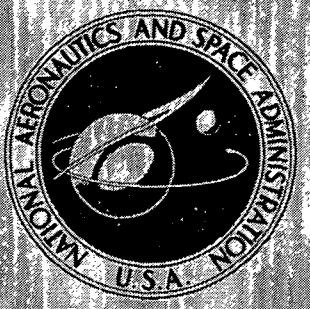

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EARTH-ORBITING SPACE-BASE CREW SKILLS ASSESSMENT

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Many aspects of the crew skills required for an earth-orbiting space base are discussed. Problems associated with the design aspects are considered, and an assessment of a line-type organization is made. The problems discussed are the crew billets related to work periods, cross skills, manpower allocation, weekly crew schedules, duty cycles, and crew efficiency. Crew compartmentation and crew distribution are also discussed and analyzed. The study results, problem areas, and recommendations are presented for a nominal space-base crew.

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SUMMARY

This exploratory study presents many aspects of the crew skills required for an earth-orbiting space base, the problems associated with the design aspects of such a base, and a possible solution for a space-base organization. An assessment of the organization is made from a military standpoint. The principal problem discussed is crew billets as related to work periods and cross skills. Other areas covered are manpower allocation, weekly crew schedules, duty cycles, crew distribution, crew efficiency, and crew compartmentation.

The major conclusion is that a line organization, consisting of operational and technical departments, is desirable. It is further concluded that an average workweek of 6 days, based on an 8-hour workday, is the recommended workload per crewman. Furthermore, crew cross skills are a prerequisite to crew selection. The limitations of this exploratory study are recognized, and future work on this complex problem is required in depth.

INTRODUCTION

The purpose of this study is to make a preliminary assessment of crew skills for an earth-orbiting space base in a remote, confined environment. Such a study is necessary because of the major design impact of this study area on man and his associated equipment, such as: berthing, mess arrangement, power requirements, experiment-laboratory and support-facility sizing, expendables, and spacecraft logistics. This effort involves selecting a space-base organization, departments, work periods versus crew skills, experiment time allocation, and compartmentation. The space base is a facility in space which is developed to support men and equipment on a permanent basis in order to take advantage of the economics of size, centralization, and permanency. The base has six important characteristics; it is a central facility for power, volume, logistics, experimental equipment, communications, and data reduction.

Assumptions and Guidelines

The first assumption is that the Apollo Applications Program basic core flights will have been completed during the early 1970's. Secondly, a space station will be

operational in the mid-1970's. Finally, a large space base with an advanced logistics system will be operational in the late 1970's or early 1980's.

Other assumptions include a gradual buildup of the initial 12-man space station to a large space base accommodating up to 100 men by 1980. For crew convenience, a large portion of the space-base habitable volume would have artificial gravity.

The following general guidelines were used in this study.

1. The crew will consist of astronauts, scientists, engineers, and support personnel.

2. Maximum flexibility will be incorporated to allow for new experiments and to accommodate a variable crew size.

3. The docking of rendezvous vehicles will be under the control of the station commander. Docking and debarking operations will be directed from the bridge. Vectoring for man and unmanned logistics/personnel carrier/data capsules will also be accomplished on the bridge.

4. Experiment planning and execution will be accomplished on board and will include pointing parameters for celestial, terrestrial, and solar viewing.

Objectives

This study assesses space-base crew skills with the following major objectives.

1. Select a preliminary space-base organization with the required operational and technical departments to ensure mission success.

2. Provide a preliminary assessment of work periods versus crew skills.

3. Estimate the total weekly man-hours required for operational crew support functions during nominal inflight work periods.

4. Establish a time line for a weekly crew schedule for a nominal crew size of 60 crewmen.

5. Explore the crewman distribution and compartmentation problem based on relative crew rank.

ABBREVIATIONS AND ACRONYMS

AGM	artificial-gravity module
agr.	agricultural
assm.	assembler

asst.	assistant
att.	attendant
av	average
biomed.	biomedical
biosci.	bioscience
biotech.	biotechnology
cafe.	cafeteria
comdr.	commander
comm.	communications
cont.	control
dep.	deputy
dept.	department
dir.	director
DMS	data management system
DNA	deoxyribonucleic acid
DP	data processing
D. V. M.	Doctor of Veterinary Medicine
EC/LS	environmental control/life subsystems
EI	experimental investigator
elec.	electronics
electromech.	electromechanical
EMI	electromagnetic interference
engr.	engineer
EOSB	earth-orbiting space base
EPS	electrical power system
ET	experiment technician
EVA	extravehicular activity

fab.	fabricator
G&C	guidance and control
genl.	general
geod.	geodesist
G&N	guidance and navigation
hskp.	housekeeping
instr.	instrument
IVA	intravehicular activity
journ.	journalist
KP	kitchen police
lab	laboratory
log.	logistics
lt.	lieutenant
lt. comdr.	lieutenant commander
mach.	machinist
maint.	maintenance
math.	mathematician
matl.	materials
max.	maximum
M. D.	Doctor of Medicine
mech.	mechanical
med.	medical
met.	metallurgist
mfg.	manufacturing
mgr.	manager
mgt.	management

min.	minimum
mon.	monitor
mon./cont.	monitor/controller
M&R	maintenance and repair
NP	nuclear power
NPM	nuclear power module
obs.	observer
OCS	onboard checkout system
off.	officers
OLC	operations and logistics control
opns.	operations
opr.	operator
Ph. D.	Doctor of Philosophy
photo.	photographic
photog.	photographer
phys.	physical
psych.	psychiatrist
psychol.	psychologist
pwr.	power
res.	research
R. N.	registered nurse
SDC	safety and damage control
spec.	specialist
sup.	supervisor
surv.	survival

sys.	systems
tech.	technician
tfc.	traffic
TV	television
USN	United States Navy
weld.	welding
wts.	weights

APPROACH

Nuclear-Submarine Analysis

The nuclear submarine is a good space mission analog. The basic characteristics of the submarine mission have similarities to those of the long-duration earth-orbital space-base (EOSB) mission with operational activities within isolated, confined, and hazardous environments. Consequently, a nuclear submarine and a space base may be reasonably compared in terms of relative habitat size and accommodation; crew size; mission duration and related stresses; mission operational activities in a moving, remote, hostile, and confined environment with limited resupply capability; long-duration human performance; and autonomy.

Therefore, the nuclear-submarine operating experience is very significant and applicable with many analogies to the space base. The nuclear submarine is an operational vessel in which crews of 90 to 130 men are isolated for 60 to 90 days. Many common areas of interest and comparability exist, such as habitability and environmental control; trace contaminants, including interactions between contaminants and life-support equipment; human-factor aspects, including work-rest cycles; medical (med.) aspects, both physiological and psychological; and onboard maintenance (maint.) experience.

A functional diagram depicting a typical United States Navy (USN) nuclear-submarine line-type organization with a crew complement of 94 men is shown in figure 1. The organization is subdivided into six departments: navigation, operations (opns.), weapons, supply, medical, and engineering. The line of authority proceeds from the commanding officer assisted by an executive staff, and a line officer is in charge of each department (dept.). Ideas and orders travel strictly according to this line of authority. The organization and departmental responsibilities are briefly itemized as follows.

1. Commanding officer: commander (comdr.)

2. Executive officer: lieutenant commander (lt. comdr.)

3. Executive staff

a. Responsibilities: Assist the executive officer in discharging his administrative responsibilities.

b. Personnel involved: Three enlisted men

(1) Chief of the boat (ranking noncommissioned officer)

(2) Two yeomen

4. Navigation Department

a. Responsibilities: Safe navigation and piloting of the ship

b. Personnel involved: One officer and four enlisted men

(1) Navigator and electronics (elec.) officer (lt. comdr.)

(2) Quartermaster chief and three enlisted men

5. Operations Department

a. Responsibilities: Preparation of operation plans, gathering intelligence, and maintaining effective communications (comm.)

b. Personnel involved: One officer and 14 enlisted men

(1) Communications officer (lieutenant (lt.))

(2) Four radio and communications men

(3) Four sonar technicians

(4) One electronics technician (tech.)

(5) Five seamen (phone talker, etc.)

6. Weapons Department

a. Responsibilities: Operation, maintenance, and repair of missiles and torpedoes

b. Personnel involved: One officer and seven enlisted men

(1) Weapons officer (lt.)

(2) One missile technician

(3) One fire-control supervisor (sup.)

(4) Five fire-control technicians

7. Engineering Department

a. Responsibilities: Operation, maintenance, and repair of main propulsion machinery, reactor and electrical installations, and auxiliary equipment; damage and casualty control; ship maintenance and repair (M&R), and so forth.

b. Personnel involved: Four officers and 45 enlisted men

(1) Engineering officer (lt.)

(2) Main propulsion assistant (asst.) (lt.)

(3) Electrical/reactor officer (lt.)

(4) Damage control assistant (lt.)

(5) One electronics technician chief (radar, sonar maintenance)

(6) Six electronic technicians

(7) One electricians mate chief (power)

(8) Six electricians

(9) One interior communications chief

(10) Six interior communications technicians

(11) One machinist (mach.) mate chief

(12) Eight machinists

(13) One engine man chief

(14) Eleven engine men

(15) Three firemen/messmen

8. Supply Department

a. Responsibilities: Operation of the general mess, supervision of general supplies, administration of funds, and control of spare parts.

b. Personnel involved: One officer and eight enlisted men

(1) Supply officer (lt. (junior grade))

(2) One storeman

(3) Four stewards (cooks and dishwashers)

(4) Three supply disbursing clerks

9. Medical Department

a. Responsibilities: Treatment of the sick and wounded; supervision of health, sanitation, hygiene, radiation protection and decontamination, and atmosphere gas analysis; and first aid instruction.

b. Personnel involved: One officer and two enlisted men

(1) Medical officer (lt.)

(2) One hospitalman chief

(3) One hospitalman

As may be seen from the preceding breakdown, the total manning of a typical nuclear submarine includes 11 officers and 83 enlisted men, or a total of 94 crewmen.

In an effort to obtain further insight into the space-base crew-sizing problem, a study was made of submarine-mission patrol duty assignments in a similar moving, remote, and hazardous environment. For example, the four submarine patrol duty assignments are classified as "normal cruising," "battle stations missile," "battle stations torpedo," and "maneuvering." Typical watch, quarter, and station bills are listed in table I by USN personnel required for each patrol condition. A station bill, or billet, by definition is "to assign a person to a post" or to a duty assignment. This duty assignment analogy appears to be applicable to the space-base mission as a reference point.

The operation of an orbiting space base for a long-duration mission will depend on the ability of each crewman to perform the tasks assigned to him. An important crew-sizing problem is the related volume considerations for the space-base crew quarters which is an important element of habitability. Therefore, proper crew-quarters sizing will maintain crew morale and permit optimum performance in a submarine or a comparable space base.

Consequently, the USN environmental control standards, submarines category, were utilized for quantitative apportionment among living-area elements as a preliminary space-base design philosophy in which the living quarters arrangement and square footage per man is a prime reflection of responsibility level. For example, submarine crew-quarters sizing is based on three relative rankings: commanding officer, line officers, and enlisted men, where the philosophy of "rank has its privileges" is recognized in keeping with military tradition.

Offshore Drilling Rig

A typical offshore drilling rig was briefly compared to the space base. This offshore drilling rig is an operating, oil-producing rig in which crews of 50 to 65 men are isolated in a sea environment located 8 to 10 miles off shore for long periods of time. The offshore quarters are designed with an integral roof/heliport, and two decks are provided for living quarters. The quarters have supply provisions for a maximum of 65 men for 6 months. The crew is typically rotated on a 6- to 8-week basis, although 3 weeks would be preferable from a morale standpoint. The offshore quarters are designed to be explosion proof and to withstand hurricane winds with an environment of rain, fog, high winds gusting up to 40 mph, and 7-foot sea states. The helicopter transports personnel and delivers spare parts and equipment.

The organization of a typical offshore drilling rig crew is as follows:

1. Supervisory personnel

    a. Drilling superintendent

    b. Assistant drilling superintendent/radioman

    c. Tool pusher

2. Galley staff

    a. Three cooks to provide three meals a day for two shifts

    b. Two messmen for the cafeteria (cafe.)

3. Housekeeping (hskp.) staff

    a. Two housekeepers responsible for cleanup room, recreation area, card rooms, and change room

    b. One maintenance man for general (genl.) facilities maintenance

4. Operational staff: 39 to 54 crewmen (drillers, derrick men, and roughnecks)

The first floor of the crew living quarters contains a 360-square-foot galley area with a 612-square-foot cafeteria/mess hall furnished with three 10-man tables. A 476-square-foot recreation room is also provided, containing four couches, a television (TV) set, and a projection screen for viewing motion pictures. A 120-square-foot card room is adjacent to the cafeteria area. A 592-square-foot change room containing 30 lockers, benches, lavatories, urinals, and two water closets is provided for cleanup after work-shift duty and includes a 175-square-foot shower room. A 144-square-foot laundry room contains two dryers, two washers, two water heaters, and sinks.

The drilling superintendent is the only man with a private sleep area. His 144-square-foot quarters contain a bunk, couch, desk and chair, and three lockers. He also has an attached bathroom with a lavatory, water closet, and shower. Adjacent

to the private sleep area is the office and radio room, which the superintendent shares with his assistant. The office and radio room contains two desks and chairs, two conference chairs, radio equipment, file cabinets, and a bookcase.

The second floor of the living quarters contains 16 bedrooms with four men assigned to each room. A maximum of four men to a bedroom is desirable because past experience has revealed that personality problems arise with more than four men to a bedroom. Although United States Coast Guard regulations require a minimum sleep area of 160 cubic feet per man, it is felt that less than 200 cubic feet deprives a man of equipment affecting morale. Therefore, each bedroom contains two double bunks with reading lamps, a desk and chair in front of a window dividing the bunk space, private lockers, and one lounge chair. Each bedroom has a 120-square-foot area with a floor-to-ceiling height of approximately 6 feet 9 inches. In the center of this living area, surrounded by 4-foot-wide passageways, is a 528-square-foot head containing eight lavatories, eight water closets, three showers, and three urinals. This central area also contains a central linen closet of 80 square feet and a 120-square-foot TV or card room for recreation.

SPACE-BASE ORGANIZATION

As previously noted in the nuclear-submarine analysis, the submarine is an excellent space-mission analog. A space-base line organization is synonymous with military and many major industrial organizations. The line organization is very stable, and ideas and orders travel strictly according to the line of authority. There never is any question as to who is in command.

A functional diagram depicting an exploratory, analytical approach, based on the nuclear-submarine analysis, for a line organization with an initial estimated crew complement of 69 is shown in figure 2. The appendix contains a complete list of 106 possible crew positions and the related duties and major skill of each crewman. The appendix also describes the depth of crew skills for each position (primary and special), the work responsibilities, and the estimated number of task categories.

The EOSB organization is subdivided into an Operations Department and a Technical Projects Department. The Operations Department is responsible for the preparation of operation plans, effective communications, maintenance and repair, and operation evaluations. The systems manager (sys. mgr.) supervises the Telecommunications Group, the Systems Management (Mgt.) Group, and the Navigation Group. The operations and logistics control (OLC) manager is responsible for the Supply Group, supervision of general supplies, food preparation and serving, housekeeping, station logistics (log.), and cargo transfer.

The Technical Projects Department is responsible for crew medical status, in-flight experiments, and the related acquisition of data. The technical director (dir.) supervises the Astronomical Observatory, the Space Applications Group, and the Experiment Support and Operations Office. The flight surgeon supervises the Biomedical (Biomed.) Office, which is responsible not only for obtaining basic medical/behavioral data but also for all medical activities associated with crew well-being

and environmental atmosphere control. The flight surgeon also supervises the Biotechnology/Bioscience (Biotech./Biosci.) Office, which is responsible for an intensive experiment program.

Operations Department

The Operations Department is staffed by an estimated 34 crewmen as shown in table II. The Operations Department (Station Operation and Maintenance) is responsible for maintaining effective communications and operational status. This department is also responsible for the operation, maintenance, and repair of all operational electronic equipment as well as the operation and monitoring of all station control panels. The possible order in which crewmen staff the space base is shown in tables II and III. An initial contingent of 12 crewmen is required to activate the station, and the second (12 crewmen) and third (10 crewmen) contingents are required to establish a working space base. Crewmen will be added in increments of 10 on the fourth, fifth, and sixth contingents, and nine more crewmen will make up the seventh and final contingent, completing the ultimate crew of 69 men on board when the space base is fully assembled in earth orbit.

The Telecommunications Group (11 crewmen) is responsible for communications, data management, and the command control (cont.) center. Specifically, the Telecommunications Group maintains effective communications between the space base and the earth, the logistics spacecraft, and subsatellites, and within the space base. Communications, instrumentation, and crew-station controls and panels comprise an integrated telecommunications subsystem, including data management. This group also analyzes and edits onboard data, rejects undesired data, and stores data on board the space base.

The Navigation Group (three crewmen) is responsible for orbital navigation, attitude and altitude control, and operation of the direct control systems at the command-center console. This group is specifically responsible for maneuvering and docking control of other space vehicles.

The Systems Management Group (seven crewmen) is responsible for systems monitoring and control, inspections, systems and structures maintenance, service, and repair. This responsibility specifically involves maintenance and repair activity associated with power (pwr.) systems, crew safety, damage control and containment, and radiation monitoring and control.

The Supply Group (nine crewmen) is responsible for the supervision of general supplies, control of spare parts, food supplies, food preparation and serving, and community housekeeping. The group is also responsible for activity associated with station logistics and the transfer of cargo and supplies from and/or to the logistics spacecraft.

Technical Projects Department

The Technical Projects Department is staffed by an estimated 35 crewmen, as shown in table III. This department is responsible for the setup, programing, and

performance of inflight experiments and the related acquisition, formatting, and reporting of information and data. Crewmen in this area may participate in system management or command functions or may draw from those same areas to supplement their requirements. The Astronomical Observatory (three crewmen) is responsible for the operation of telescopes and survey instruments for the study of radiation from the sun, planets, and stars throughout the spectral regions. The Space Applications Office (nine crewmen) is responsible for investigations in the areas of earth resources, meteorology, oceanography, communications, traffic (tfc.) control and navigation, geodesy, and advanced technology. The Experiments Support and Operations Office (six crewmen) is responsible for experiment support and operations as directed by technical project requirements. The Biomedical Office (seven crewmen) is responsible for obtaining basic medical/behavioral data in zero-gravity and artificial-gravity environments. The Biotechnology/Bioscience Office (eight crewmen) is responsible for a broad spectrum of life-sciences experiments which will make effective use of the scientists' skills.

The Astronomical Observatory Group (three crewmen) is responsible for the highly automated operation of telescopes and survey instruments above the atmosphere to study radiation from the sun, planets, and stars throughout the spectral regions from high-energy gamma rays to long-wavelength radio waves. Although the observatory is highly automated, man is required in the areas of maintenance and repair, instrument checkout, calibration, adjustment and updating, data handling, and selection of targets.

The Space Applications Office (nine crewmen) is responsible for earth applications, such as remote monitoring of surface and atmospheric features in the areas of agriculture, forestry, hydrology, oceanography, geodesy, geology, and meteorology. This office will also study the space environment (space physics) and its effects in earth orbit and will investigate the astrophysical aspects of cosmic radiation. Man-machine evaluations will be conducted by this office, including such activities as time-and-motion studies, maintenance and repair, and social and psychological integration. The Space Applications Office will also investigate space manufacturing (mfg.) processes and advanced technology. This office is responsible for communications, navigation and traffic-control experiments designed to support the development of advanced systems for earth-orbital and deep-space communications, autonomous onboard navigation, and control of ships and aircraft. Experiments in the area of traffic control will be conducted to develop technology applicable to position measurement.

The Experiment Support and Operations Office (six crewmen) is responsible for experiment support and operations as dictated by the technical project requirements. The specific responsibilities of this office include experiment-related mission photography and TV, historical documentation, public affairs management, photographic laboratory (photo. lab) support, and closed-circuit TV. This office is also responsible for planning, setting up, testing, and reporting of test programs; earth- and space-surveillance monitoring and support; manufacturing process support; maintenance and repair of experiments and related equipment; and chemical and instrumental analysis.

The Biomedical Office (seven crewmen) is responsible for obtaining basic medical/behavioral data in zero-gravity and artificial-gravity environments. These include data in such areas as alveolar-arterial oxygen gradient, regional blood flow, venous pressure, cardiac output, onboard hematological measurements, breath-by-breath measurements, oxygen consumption and carbon dioxide production, bone

densitometry, neurophysiology, behavioral effects, metabolism, and microbiology. This office is also responsible for all medical activities associated with crew well-being including diet, atmosphere monitoring, preventive medicine, personal hygiene, therapeutic medicine, physical (phys.) fitness, and exercise-equipment control.

The Biotechnology/Bioscience Office (eight crewmen) is responsible for an intensive experiment program concerning the biological effects of earth-orbital flight on the physiology, morphology, and behavior of various organisms, including primates, rodents, invertebrate animals, plants, and single cell organisms. Space biology will continue the investigation of organisms and phenomena that are indicated by prior survey experiments to warrant further intensive study. It can be postulated that the elements of the experiment complex will be adaptations of the earlier elements of Bio A - Primates, Bio C - Microbiology, Bio D - Small Animals, Bio E - Plants, and Bio F - Invertebrates.

Crew Composition Analysis

Besides selecting a space-base organization, it is necessary to analyze the crew composition relative to a logical space-base buildup. The primary 12-man crew for the space base could grow to 100 men based on the scientific and technological objectives of the mission. During preparation for this mission, the crewmembers will have been familiarized with the operation and care of the onboard equipment. Throughout the preflight training experiences, every effort will be made to establish team relationships. These crewmen will receive various medical and psychological tests and will have had extensive personal interaction in order to determine crewman compatibility.

Crew composition as a function of crew size, coordinated with the space-base buildup of 40 to 100 crewmen, is shown in table IV. This table is the result of an analysis of all the required jobs outlined in the preceding sections. The mission planners, as previously stated, foresee a gradual incremental buildup of the initial space station to a large space base accommodating 100 men by 1980. A balanced crew mix must always include astronauts, scientists, engineers, and station personnel. It should be noted that the Operations and Technical Projects Departments are approximately equally manned.

Therefore, the first group of 40 crewmen shown in table IV represents the initial 12 crewmen required to activate the station, supplemented by the second and third contingents to establish a minimal working space base. This group includes the executive staff and key operational-experiment-program personnel.

The rationale in determining the order in which crewmembers go on station can best be illustrated by examining types of crewmen involved in the buildup. For example, three navigators and three console operators are high-priority members of a 50-man staff, because positions must be manned on a 24-hour basis. Cooks and mess attendants are added early in the buildup to support the three eating periods per day with two shifts per meal. Three astronomers are required to man an observatory up to a maximum of an estimated 12 hours per day and are, therefore, included in the 40-man crew. Maintenance, communications, and data management personnel are also high-priority positions to be staffed.

Conversely, after a nominal crew size of 60 men has been reached, the relative order becomes less critical. However, a logical progression is still necessary. A psychiatrist/chaplain (psych./chaplain) takes precedence over a pharmacist in crew planning because the Biomedical Office could continue to absorb this duty. A safety and damage control (SDC) officer is certainly more necessary than a dental surgeon or a test-operation technician.

In summarizing the space base organization discussion and prior to a discussion of the crew skills, it should be noted that the organization presented is dependent upon the type and importance of the experiment program and upon the operational problems encountered. The organization of the Technical Projects Department is based on a typical experiment program embracing all apparent scientific disciplines. It should be recognized that temporary variations in the emphasis of the experiment program will almost certainly result in fluctuations in the nominal crew list presented herein.

CREW SKILLS

The space-base organization previously outlined in this report and the related crew sizing are interrelated with crew skills. Crews will be selected on the basis of their primary or basic skills and special skills that may be either taught or selected to achieve the desired balance of capabilities among size-limited crews. Cross skills are the result of cross training enough crewmembers to provide a broad base of capabilities and an assurance of high reliability in crew performance. Furthermore, any discussion of crew skills in the analysis of crew composition and sizing should recognize the related crew factors of duty assignments, cross skills, manpower allocation, duty cycles, and crew efficiency.

Duty Assignments

Closely associated with crew size are the particular crew skill positions that correspond to major functional duty assignments. Table V shows (1) crew duty assignments in five operational conditions for the initial 12 crewmen who are required for either the precursor space station or for space-base activation and (2) the necessary cross skills required for maximum crew utilization.

During the nominal inflight condition, the space base is in a "housekeeping" status with experiments performed at a relatively unhurried pace. The critical flight condition is defined as that intensive work status during which mission-critical events take place such as logistics resupply, docking operations, orientation, navigation sightings, and course corrections. During the subnominal inflight condition, mission activities are minimal (operations, maintenance, and experiments) and time is available for drills, inflight training programs, and evaluations. Contingency conditions occur during unscheduled maintenance and unforeseen variations in experiment procedure. An emergency condition occurs during potentially catastrophic situations such as fire, meteoroid puncture, or radiation hazards. The nominal inflight condition will constitute the greater part of the mission duration and may be considered the crew long-term endurance work compared to the relatively short-term, intensive crew activity.

Cross Skills

In order to illustrate the required cross skills, the staff needed for operation of the initial space station, or for space-base activation, was used as a typical example. The initial complement of 12 crewmen was selected to satisfy the following station-crew operations workload: a commander/pilot who commands and controls the space station; a deputy command pilot responsible for guidance and navigation (G&N), spacecraft critical maneuvers, and navigation sightings; a flight surgeon to serve as medical monitor and experimenter and as sick bay physician; a communicator to handle communications and the data management system (DMS); a flight operations engineer (engr.) to program daily operations; a senior scientist who is responsible for the command and control of experiment equipment; and a technician/repairman for inflight checkout and maintenance. Observers are needed to select, observe, and identify targets of opportunity. Interpreters are also required to communicate the interpretations to earth. The crewmen must also perform as medical test subjects, photographers, specialists in extravehicular and intravehicular activity (EVA and IVA), drill and crew-training specialists, and damage and control specialists. Tables VI, VII, and VIII present the suggested crew skills for the experiment program which reflects the recommendations of two NASA contract studies (refs. 1 and 2).

The relationship of cross skills to duty assignments can be best illustrated by the many skills of the space-base commander, crew position number 1. This man should be an experienced astronaut/engineer and executive, preferably with a military command background. During the nominal inflight condition, his major function is in an executive capacity as EOSB manager who commands and controls the space base on a 24-hour basis subject to call at any time to assume his prime responsibility. However, he also functions as the navigator in the command center during the nominal and critical conditions and supervises logistics supply. During the subnominal inflight work period, he is available for the roles of communicator and DMS assistant. He is also a medical test subject, as are all other members of the crew except the flight surgeon. During the contingency condition, his professional capacity as an electrical engineer is important in the flexible experiment program and for unscheduled electrical maintenance. In an emergency condition, he is the damage control officer.

Crew Efficiency

One critical factor to be considered for a long-duration mission will be the psychological implications of the space environment on the well-being and performance of man in space. Behavioral observations will eventually determine the number of crewmen needed and the variety and number of activities to be provided to crewmembers to assure their continuing effectiveness. Crewmen with a minimum of astronaut-type training or physical conditioning will be living and working in space for long periods of time. However, some trained astronauts are still needed to perform physical and mental tasks while under stress.

The Apollo Application Core Program estimated experiment-scheduling efficiency is 66 to 75 percent, depending on the type of experiments. However, the present trend of productivity in the economy of the United States indicates a slowing process. A recent study of office workers by James M. Duncan indicates that manpower utilization in

most offices rarely exceeds 60 percent and in some operations may fall below 40 percent. There is also an average loss of 28 percent "through plain inefficiency."

Although not strictly skills, personality traits such as leadership, social adjustment, and motivation must be considered. Physical attributes such as good health, aging effect, and physical fitness are important. The following human factors are considered pertinent to the efficiency study:

1. The space-base crewmen should generally be in the 25- to 40-year age bracket. The USN Sea Lab aquanauts are in this age range. In July 1968, the 52 astronauts stationed at the Manned Spacecraft Center were in the 25- to 45-year age range. At 25 years of age, a candidate is at a prime age level for preflight training programs and can be expected to perform in space flight. After the age of 40, there is a definite aging effect and a slower functional process.

2. Social patterns are a factor in a space-base organization comprised of a mixture of astronaut/engineers, scientists, technologists, technicians, and support personnel from many social levels. As on earth, crewmembers will tend to associate with those of equal status. To avoid impairment or loss of efficiency, these social patterns should not be disturbed or violated.

3. Crew rotation is planned within a time line of approximately 180 days. However, lassitude resulting from prolonged stress or mental fatigue is a critical condition that causes the early return of crewmen (ref. 3). Predictive medicine with periodic tests can detect early deterioration of well-being and performance by extrapolating trends and can permit predetermination of man failure. Fatigue can be overcome through exercise, recreation, rest, and relaxation.

4. Crew job rating is a critical factor in a space-base team selection. Highly desirable attributes that a candidate should possess for this team are an athletic background, work experience, excellent grades, and sociability. Because this is an autonomous space base with a line organization, personnel with present or past military or "organization man" experience are highly qualified for duty.

WEEKLY CREW SCHEDULE

Operations Department Man-Hour Allocation

Time allowances are closely related to crew duty positions and duty cycles. The basic crew-time utilization is based on a typical workday as shown in table IX. This schedule allows 8 hours per day for work and is independent of crew size and the necessary crew activities, such as station operation and maintenance, communications/data management, maintenance and repair, the onboard checkout system (OCS), personal and community tasks, drills, and training. The normal workweek per crewman is 6 days, or 48 hours.

Table X shows the major job functions of each operations crewman and the time and duty cycles associated with each function. It also illustrates the correlation between crew skills and job functions. Executive staff meetings are held once each week,

3 to 4 hours per week. Continuous duty is defined as an unbroken work period (except for a meal break) performed at some time within a 24-hour day. Intermittent duty is defined as stopping and starting at predetermined intervals or pausing from time to time. Thus, intermittent duty is characterized by periodic intervals. Variable duty is subject to change during a 24-hour period by a flexible experiment program or by operational changes. Variable and intermittent duty may also be combined as dictated by the nature of the position. The cyclic 4 hours on, 4 hours off, 4 hours on is dictated by watch-type positions where physical exertion or mental stress limits efficiency beyond a 4-hour period.

A typical daily executive time allocation is reflected in the duties of the deputy commander, who spends 2 hours at the command-center control console in the role of navigator, 1 hour reviewing the operations log and schedule, 2 hours performing operational evaluation, 1 hour performing space-base inspection, and 2 hours making station-management decisions. Another example of off-nominal work-time allocation is the systems monitors and controllers, who spend 4 hours on, 4 hours off, 4 hours on at the command-center console monitoring and controlling areas such as the caution and warning system, subsystems, the OCS display, video, audio, and communications.

Crew Duty Cycles

Planning of daily space-base duty cycles should reflect strong consideration for circadian rhythms. Table XI relates the types of crew positions to the typical duty cycles during a nominal workday. It summarizes the duty-cycle data of table X and includes similar data for the Technical Projects Department.

Many operational and experiment duties are cyclic because of the three-shift (24-hour duty) requirement of a particular job. For example, the navigators and control-console operators serve in the command center on this duty cycle.

The commander and the deputy commander are charged with the overall responsibility of space-base management during any given 24-hour day, normal or otherwise. As a result, their schedules are almost entirely variable. The officers' (off.) steward adjusts his schedule to serve the executive staff and the senior scientists. The maintenance officer and technicians have a variable schedule because of the nature of their jobs. The management analyst, whose duties are primarily administrative, works on an 8-hour continuous duty cycle.

The communications officer and the power systems officer serve a daily tour of duty in the command center, while the DMS officer does likewise in the DMS laboratory All three officers also have systems housekeeping duties to perform as required. The schedule for the cooks and mess attendants is intermittent to conform to meal preparation, serving, and cleanup requirements.

Earth and space surveillance is on a continuous day/night cycle, largely automated, but man-tended. Hence, the experimenters fall generally into the category of 8 hours continuous duty. However, experiment changes or programs may increase work periods to 10 hours per man, with a maximum of 16 hours continuous duty.

Operations Department Schedule

Based on the daily crew-time utilization established in table IX, a weekly crew schedule (complete profile), during a nominal inflight work period, was derived for a 60-man crew. The crew composition key-related to the weekly crew schedule is shown in table XII. The weekly crew schedule for six key executive positions is shown in figure 3. The Operations Department weekly crew schedule for 26 crewmen is shown in figure 4. The time-line program tabulates a schedule for each crewman by hours and days for a 48-hour work week. The beginning of each 24-hour day is referenced to 6:00 a.m. at Cape Kennedy, Florida, starting on Monday morning. The executive staff observes a typical day shift. From 6:00 a.m. to 8:00 a.m., the crew devotes its time to eating breakfast in two shifts, either in the crew cafeteria or in the officers' mess. This staggered schedule not only reduces the maximum load on the cafeteria but permits most work stations to be manned continuously for 10 hours a day. Either from 8:00 a.m. to 12:00 noon or from 9:00 a.m. to 1:00 p.m., the crew works the morning shift with an hour for lunch and relaxed conversation. The 9:00 a.m. to 1:00 p.m. shift enjoys 1 hour devoted to recreation and exercise before beginning the workday. The afternoon work schedule is 1:00 p.m. to 5:00 p.m., or 2:00 p.m. to 6:00 p.m., followed by supper and a recreation and exercise period of 2 or 3 hours. At 9:00 p.m., the personal hygiene and housekeeping hour precedes "lights out" for an 8-hour sleep period from 10:00 p.m. to 6:00 a.m.

On weekends the crewmen typically have one off-duty day (Saturday or Sunday), which they use for further rest and relaxation, study, reading, or physical exercises. The 7th day (Sunday) is scheduled to be a minimum operational and experiment day, and the work level is reduced as reflected in the weekly schedule.

The power systems officer and the communications officer (crew positions 7 and 8), in addition to their mission duties, serve during the sleep period of 10:00 p.m. to 6:00 a.m. as "officers of the watch," performing the rotation-roster duties covered by the junior-executive engineers on a weekly tour of duty. During the day shift, the commander and deputy commander assume this responsibility. On the 7th day, crewmen 7 and 8 have an off-duty day and are replaced by roster assignment.

The guidance and control (G&C) officer, navigator, and assistant navigator (crew positions 23, 24, and 25) serve in the role of navigator in the control center on a 24-hour duty basis. The 6th and 7th days are off-duty days for these crewmen, on the basis of one navigator per day, and they are replaced by other astronaut/navigators on board according to a rotation duty roster. Eating periods are at odd hours, but an open crew cafeteria where food warmers and liquid coolers are available would alleviate the food problem.

The four systems monitors/controllers work a 44-hour week with Sunday, Monday, Wednesday, and Thursday as the off-duty days. This schedule permits an additional one-half day off duty once a week. Once a week, each operator has a 7-hour sleep period followed by a 1-hour nap later in the day. The main advantage of this schedule is that the four operators can cover the monitoring operation on a 24-hour-per-day basis, 7 days a week.

The work periods for the cooks and mess attendants (crew positions 28 to 31) are related to three eating periods per day, two shifts per meal. This creates a duty cycle

of two 3-hour work periods and one 2-hour work period to allow for food preparation, serving, and cleanup. On the 7th day, the staff has one cook and one messman on duty, and they are assisted by crewmen from a "kitchen police" (KP) roster as required.

The crew sizing of the space-base command center is related to the crew selection required to provide command/control capability and to monitor and direct operations of the space base. Three rotated positions on a 24-hour basis, 7 days a week, are required, namely officer of the watch, navigator, and systems monitor/controller (sys. mon./cont.). One additional crewman is required to monitor the experiment control systems.

Technical Projects Department Schedule

The Technical Projects Department weekly crew schedule is shown in figure 5 for 28 men who all work the typical day shift. The Space Applications Office (crew positions 33 to 39) works the regular shift 5 days per week. On weekends, the meteorologists and geologist alternate off-duty days to cover a 7-day time line. Other officers follow a similar schedule.

This time line covers a normal 8-hour day, but it is likely that the experimenters may work longer than that. For example, two astronomers are normally required to man the observatory up to a maximum of an estimated 12 hours per day. The experimenters' work schedule is obviously irregular and erratic because of the nature of the experiments, resulting not only in more hours per 24-hour day but also in different hours within that time line.

Crew-Schedule Comments

An analysis of the weekly crew schedule for the 60-man crew revealed the following pertinent facts:

1. Fifty-one of the 60 crewmen have a regular sleep cycle of 10:00 p.m. to 6:00 a.m.

2. Thirty-four of the 60 crewmen have Sunday as an off-duty day, 24 men have Saturday, and two men have Friday.

3. The staggered schedule permits most work stations to be manned continuously for 10 hours a day.

4. A rotation roster is a necessity, especially on weekends, to cover duties for a specified period of time, such as officer of the watch, navigators, KP, and messmen.

5. A "coffee break" of at least 10 minutes is mandatory for console operators at the midpoint of a 4-hour shift because of the mental alertness required.

6. Most of the crew eat at regular hours except for the officers of the watch, navigators, and console operators, who eat at irregular hours, primarily because of night-shift duty.

CREW COMPARTMENTATION

Berthing and the relative volume considerations for the crew have a major impact on performance and morale. The USN environmental control standards, submarines category, were adopted for quantitative apportionment among living-area elements of the space base. The crew compartments were investigated according to submarine crew-quarters allocation based on three relative rankings: commanding officer, line officers, and enlisted men, where the philosophy of "rank has its privileges" is recognized. This line approach resulted in the executive staff (six crewmen) rating private office-type quarters with private bedrooms and in the senior-scientist class (14 crewmen) rating semiprivate quarters. All other crewmen are quartered in quadruple compartments. Four crewmen to a room is the maximum recommended because personality problems tend to arise when a room is occupied by more than this number of men, as previously stated.

Table XIII shows a typical four-deck arrangement for 60 crewmen utilizing single, double, and quadruple compartments. The specific compartment assignments are based on minimum disruption of normal social patterns.

CREW DISTRIBUTION

One of the major impacts on the space-base program is the daily space-base crew distribution for an average workday in terms of manloading per module and the limits of occupancy, including the major crew activities in each module and/or compartment. A basic space-base configuration is illustrated in figure 6.

Man-Hour Schedule Correlation

An approach to the crew distribution problem is shown in table XIV, which gives the work, rest, and off-duty time spent in various modules by typical crewmembers during a nominal 24-hour day. For example, the commander sleeps in the artificial-gravity module (AGM) 1 of the living quarters for 8 hours and also spends 5 hours off-duty there. He spends 3 hours in AGM 2 during his exercise and relaxation period. Half of the commander's work period is also spent in AGM 1. The other 4 hours are divided throughout the space base as shown. In this particular group, most of the time is spent in the living-quarters area (AGM 1 and AGM 2). If 10 experimenters had been listed as an example, more work hours would naturally be shown in the hub modules.

Space-Base Schedule Correlation

Table XV shows the daily space-base estimated crew distribution for increments of 12, 24, 30, 40, 50, and 60 crewmen to determine the average, maximum, and minimum manloading per module. This determination was accomplished by a preliminary analysis (table XIV) of each crew position in each module as a function of time (24-hour day), where 16 hours per day are spent in the living quarters for the sleep and off-duty periods and the work period is variable. As an example, extending the analysis of

table XV to a crew of 40 reveals that 388 man-hours per day are spent in AGM 1. A maximum of two crewmen are estimated to be in each nuclear power (NP) substation. The major manloading occurs in AGM 1 and AGM 2, where each man spends 16 hours of sleep and off-duty periods per day. The command center, mess facilities, and maintenance shops are located in the same area, which results in a large number of crewmembers spending all their time here.

CONCLUSION

Concluding Remarks

These concluding remarks are based on the technical analysis and data derived from this exploratory crew assessment study. The study contains a broad view of the general problems encountered in a summary, preliminary crew evaluation that impacts the design of the space base in many aspects, including the open problem areas.

1. A line space-base organization, consisting of an Operations Department and a Technical Projects Department, appears to be the most promising selection in order to ensure mission success.

2. Five inflight crew operational conditions for the space base have been tentatively defined: nominal, critical, subnominal, contingency, and emergency.

3. Crew cross skills are related to work periods and tend to reduce the number of crewmen required.

4. The significant human factors pertinent to crew efficiency are aging effects, social patterns, lassitude, and crew selection.

5. The approach to crew-quarters allocation is based on the military philosophy of "rank has its privileges." Under this system, private compartments are provided for the executive staff, semiprivate compartments for senior scientists, and quadruple compartments for all other crewmen.

6. The crew distribution analysis revealed that the major manloading occurs in the artificial-gravity modules.

Recommendations

Recommendations are made with respect to the following items.

1. A normal work schedule should consist of 8 hours a day, 6 days a week, with the majority of the crew sleeping from 10:00 p. m. to 6:00 a. m. Cape Kennedy time.

2. A space-base line organization consisting of an Operations Department and a Technical Projects Department should be adopted with a nominal crew size of 69 men.

3. The five operational conditions recommended for crew duty assignments are nominal, critical, subnominal, contingency, and emergency.

4. Crew cross skills should be a significant factor in operational selection.

5. For planning purposes, duty cycles such as variable, continuous, intermittent, and 4 hours on, 4 hours off, 4 hours on should be considered in daily time-line work allocations.

6. For planning purposes, a maximum work scheduling efficiency of 75 percent and a minimum of 66 percent should be considered.

7. Operational space-base crewmen should generally be in the 25- to 40-year age bracket.

8. A preflight psychological-test period is required to establish crew social and work patterns for the selection of crew quarters and team compatibility. Matching of crew personnel on the basis of psychological compatibility is an important factor in mission success.

9. A station watch is required on a 24-hour-day basis.

Open Problem Areas

The present status of the crew-skills assessment problem suggests that additional investigations are required to optimize man's performance capability in the isolated space environment. Crew performance should be investigated to determine man's zero-gravity and artificial-gravity capability. Further study of the man/machine interface is required to determine the optimum degree of automation. An in-depth study is also required to determine the exact number of crewmen and the crew mix required for a successful mission.

Further effort is required in time-and-motion and psychological studies to determine realistic crew efficiencies. A study of a long-duration mission time line is required when the experiment program and space-base configuration are better defined. Man's viability and effectiveness in space must also be resolved before long-duration missions can be accomplished. The variability and number of crew activities must be studied in greater depth in order to maintain crew effectiveness. Human factors must be studied in greater depth to obtain an optimum team based on psychological preflight tests. Sleep patterns should also be investigated, including naps versus sleep during intensive work periods, because these patterns tend to vary. Some men require only 3 to 4 hours sleep per night, while others need 10 hours sleep per night.

Psychosocial factors should be examined in depth, including isolation, confinement, limited privacy, recreation, celibacy, separation from families, and so forth. The possibility that some crewmembers may be female should be considered in future studies.

It should be reiterated and recognized that this study is an exploratory assessment of crew skills and their impact on berthing, mess arrangement, experiment-laboratory sizing, support facility sizing, and spacecraft logistics. In the process, an attempt has been made to stimulate thought on the preliminary selection of a space-base organization and on crew selection, crew size, work periods, crew skills, crew compartmentation, duty cycles, and crew distribution.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, January 30, 1970
981-10-10-89-72

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TABLE I. - TYPICAL SUBMARINE WATCH, QUARTER, AND STATION BILL[a]

Seaman	Normal cruising	Battle stations missile	Battle stations torpedo	Maneuvering
1	Assistant navigator	Assistant navigator	Assistant navigator	Assistant navigator
2	Quartermaster of the watch	Loran C operator	Loran C operator	Quartermaster/bridge
3	Navigation console operator	Navigation repair chief	Navigation repair chief	Navigation repair chief
4	Navigation console operator	Navigation console operator	Navigation console operator	Navigation console operator
5	Navigation console operator	Type II periscope	Type II periscope	NA
6	Navigation equipment technician	Navigation equipment technician	Navigation equipment technician	Navigation equipment monitor
7	Navigation equipment technician	Navigation equipment technician	Navigation equipment technician	Phone talker/ship control
8	Communication supervisor	Communication supervisor	Communication supervisor	Radio supervisor
9	Radioman	Radioman	Radioman	Lookout
10	Launch technician	Torpedoman in charge	Torpedoman in charge	NA
11	Torpedo room watch	Torpedo reload party	Torpedo reload party	Phone talker/bow compartment
12	Missile technician	Guidance technician	Guidance technician	Upper-level watch
13	Chief of the watch	Fire-control supervisor	Fire-control supervisor	Fire-control supervisor

[a]Four patrol duty assignments for 13 typical seamen based on multiskills/cross skills.

TABLE II. - OPERATIONAL PERSONNEL[a]

Crewman	Contingent						
	1	2	3	4	5	6	7
Commander	X						
Deputy commander	X						
Systems manager	X						
Telecommunications Group (11 crewmen)							
Communications officer	X						
Data management system officer	X						
Power systems officer	X						
Computer specialist/programer			X				
Operations engineer A	X						
Operations engineer B	X						
Systems monitor/controller				X			
Control console operator					X		
Communications specialist						X	
Data processing analyst				X			
Electronics technician			X				
Navigation Group (three crewmen)							
Guidance and control officer			X				
Navigator				X			
Assistant navigator				X			
Systems Management Group (seven crewmen)							
Maintenance engineer/safety officer		X					
Metallurgist/welding engineer			X				
Optical technician						X	
Mechanical technician						X	
Machinist/welder technician			X				
Instrument technician					X		
Systems housekeeping supervisor			X				
Operations and logistics control manager	X						
Supply Group (nine crewmen)							
Management analyst/weights engineer		X					
Logistics specialist/storekeeper				X			
Station's first cook		X					
Station's second cook					X		
Officers' mess attendant				X			
Cafeteria mess attendant					X		
Officers' steward						X	
Officers' steward/barber					X		
Janitor							X

[a]Operational personnel include the commander, the deputy commander, and 32 crewmen in the Operations Department for a total of 34 crewmen.

TABLE III. - TECHNICAL PROJECTS DEPARTMENT

Crewman	Contingent						
	1	2	3	4	5	6	7
Technical director	X						
Astronomical Observatory (three crewmen)							
Experiment specialist (astronomer) (Ph. D.)	X						
Experiment specialist (astronomer)		X					
Assistant astronomer			X				
Space Applications Group (nine crewmen)							
Experiment specialist (cartographer) (Ph. D.)		X					
Experiment specialist (meteorologist) (Ph. D.)		X					
Experiment specialist (geodesist) (Ph. D.)		X					
Experiment specialist (oceanographer) (Ph. D.)			X				
Experimental investigator (geology)						X	
Experimental investigator (oceanography)						X	
Experiment technician (cartography)							X
Experiment technician (meteorology)							X
Traffic control observer				X			
Experiment Support and Operations Office (six crewmen)							
Physicist/chemist (Ph. D.)			X				
Experiment technologist (mathematician/geodesist)						X	
Journalist/photographer					X		
Photographic technician							X
Chemical technician						X	
Test engineer		X					
Flight surgeon	X						
Biomedical Office (seven crewmen)							
Biomedical scientist (M.D.)			X				
Neurologist				X			
Physiologist				X			
Microbiologist (laboratory technologist)						X	
Medical technician					X		
Physical therapist				X			
Psychiatrist/chaplain							X
Biotechnology/Bioscience Office (eight crewmen)							
Experiment specialist (biologist) (Ph. D.)		X					
Experiment specialist (biochemist) (Ph. D.)		X					
Experiment specialist (microbiologist)		X					
Biologist (laboratory technologist)					X		
Biochemist (laboratory technologist)					X		
Experiment specialist (zoologist) (Ph. D.)		X					
Biotechnologist (M.D.)					X		
Veterinarian						X	

TABLE IV. - CREW COMPOSITION RELATIVE TO SPACE-BASE CREW BUILDUP

number of crewmen	Commander and deputy commander								
	Operations Department				Technical Projects Department				
	Systems manager			OLC manager	Flight surgeon		Technical director		
	Telecommunications Group	Systems Mgt. Group	Navigation Group	Supply Group	Biomedical Office	Biotech./Biosci. Office	Astronomical Observatory	Space Applications Group	Experiment Support and Opns. Office
40	Comm. officer DMS officer Pwr. sys. officer Programer Opns. engr. A Opns. engr. B Elec. tech.	Maint. engr./safety Met./weld. engr. Mach./weld. tech. Sys. hskp. sup.	G&C officer Navigator	Mgt. analyst/wts. Log. spec. First cook	Biomed. scientist Neurologist Physiologist Phys. therapist	Biologist Biochemist Zoologist Biotechnologist	Astronomer A Astronomer B Asst. astronomer	Cartographer Meteorologist Geodesist Oceanographer Tfc. cont. obs.	Physicist/chemist Test engineer
50	Sys. mon./cont. DP analyst		Asst. navigator	Off. mess att. Off. steward	Medical tech.	Lab tech. (biology) Lab tech. (biochem.) Veterinarian			Journ./photog.
60	Control console opr.	Instr. tech.		Second cook Cafe. mess att. Off. steward/ barber		Microbiologist		EI (geology) EI (oceanography)	Math./geod. Chemical tech.
70	Comm. specialist	Optical tech. Mechanical tech.		Janitor	Psych./chaplain Lab tech. (microbiology)			ET (cartography) ET (meteorology) Space surv. mon.	Photo. tech.
80		Opns. res. analyst Genl. mach./tech.		Third cook Mgt. tech./opns. Food mgt. spec.	Psych./psychol. Pharmacist	Animal att.		Earth surv. mon.	Lab tech. (microscopy)
90	Control console opr. Control console opr.	SDC officer Electromech. tech. M&R spec./painter Engineering officer		Loadmaster Supply spec.				Agr. consultant	Photo. lab tech.
100		Welder Opns. engr./ astronaut Fab./assm. tech.		Storekeeper	Dental surgeon				Matl. & weld. engr. Photo. tech/ illustrator Photo. spec. Test opns. tech. EVA spec./test subject

TABLE V.- SPACE-BASE CREW BILLETS AND CROSS SKILLS

[Inflight crew operations]

Crewman position	Nominal inflight condition	Critical flight condition	Subnominal inflight condition	Contingency condition	Emergency condition
1. Commander	EOSB manager/navigator (evaluation, decision-making) - commands and controls space base	EOSB manager/navigator, logistics officer	Communicator (comm. and DMS), test subject	Electrical engineer (experments, unscheduled maintenance)	Damage control officer
2. Deputy commander	EOSB deputy mgr./ navigator - G&N responsibilities	Navigator/logistics control officer	Experimenter/test subject (biomed., biology), EVA and IVA specialist	Chemical engineer	Safety officer. EVA
3. Flight surgeon	Medical monitor, psychological experimenter, med. experimenter	Sick bay physician (first aid treatment, sick treatment, minor surgery)	Medical monitor (sanitation, hygiene, atmosphere gas analysis, first aid instruction)	Med. experimenter (biomedicine, biotechnology)	Radiation protection and decontamination, emergency surgery, sick bay
4. Power systems officer	EPS control console operator (monitor, control, observe, and interpret)	EPS monitor	Experiment observer, comm. interpreter	EPS and related experiment support, maintenance engr./repairman	Damage control party or command-center monitor
5. Systems engineer	Systems manager and flight operations engineer (monitor, check, adjust, and assess system operation)	Communicator/DMS	Maintenance engr. (inflight checkout and scheduled subsystems maintenance)	Maintenance engr. (unscheduled maintenance, experiment support) - reprograms	Damage control party
6. Technical director	Chief scientist/ experimenter (monitor, setup, and operation) - command and control of experiments and related equipment	Experimenter (biotechnology, biomedicine, etc.)	Experimenter (biochemistry, physics, chemistry), EC/LS and crew subsystem consultant	Experimenter	
7. OLC mgr.	Operations analyst/ supply specialist (plans and schedules)	Logistics specialist	Operations evaluation (programs daily operations), test subject	General engr./mgr.	Damage control party

TABLE V. - SPACE-BASE CREW BILLETS AND CROSS SKILLS - Concluded

[Inflight crew operations]

Crewman position	Nominal inflight condition	Critical flight condition	Subnominal inflight condition	Contingency condition	Emergency condition
8. Operations engr. A	Electronics engr./console operator (monitor, control, observe, and interpret)	Experiment and systems support engr. (comm., DMS)	Maintenance engr. (electronic equipment), test subject	Instr. and elec. engr. (unscheduled maintenance)	Command center monitor
9. Operations engr. B	Electromech. engr./ console operator (monitor, control, observe, and interpret)	Experimenter/observer, interpreter, photographer	General experimenter/ systems maintenance engr., test subject	Technician/repairman	Command center monitor
10. Experiment specialist	Experimenter/ photographer	Optical physicist/ experimenter (astronomy)	General experimenter (monitor setup, operations, programing) (stellar, solar, radio)	Optical repair	Damage control party
11. Communications officer	Comm. mgr. (control station and DMS)	Communicator (comm. interpretations on station and to the ground)	Elec./instr. engr. (comm. equipment maintenance, OCS, crew station controls and panels, caution and warning system, DMS), evaluator	Electronics/instr. engr. (unscheduled maintenance, experiment support)	Communicator (caution and warning)
12. DMS officer	Assist. comm. chief (DMS mgr. - onboard analysis, filtration, transmission, or rejection of data)	Monitors incoming data, edits and evaluates data, manages tape recording and data program changes	Drilling and crew-training specialist, data collection, storage, evaluation, and editing	Same as position no. 11	Communicator (phone talker, TV monitor)

TABLE VI. - EXPERIMENT CREW FUNCTIONS

Function	Requisite skills and/or background
Astronomical observations and techniques	
Radiometry	Spectroscopy, astronomy, general physics, mathematics.
Telescope operation (stellar, galactic, and planetary observation)	Astronomy, photometry, data handling, adjustment, and servicing of diffraction-limited optical system; photographic processing.
Manned coronograph (astronomy/astrophysics, solar physics)	Coronal structure, spectra, and streamers; star identification (by map matching) to identify all objects in field of view.
Astrophysics, X-ray (astronomy)	Astronomy (star pattern recognition).
Radio astronomy (galactic noise mapping)	Manual — erection of large antenna structures (if not automatic). Technical — checkout, minor equipment repair, equipment adjustment, data interpretation, changing frequency tuning to pick up opportunities and unusual occurrences, maintaining and calibrating receivers and automatic-antenna receiver matching equipment.
Remote sensing of the atmosphere of the earth	
Conjugate aurora and airglow	Highly technical skills for observation and optical operation. Crew should contain at least one member trained in the alinement and operation of complex optical equipment and photographic recording.
Atmospheric sciences (aeronomy/meteorology)	Moderate mechanical and electrical skill, training in meteorology, target selection, calibration. Instrument engineer required for instrument maintenance procedures.

TABLE VI. - EXPERIMENT CREW FUNCTIONS - Continued

Function	Requisite skills and/or background
Remote sensing of the surface of the earth	
Multispectral tracking (geology)	Multisensor operation, geosciences, data reduction and interpretation, event observation, site selection, equipment checks, film transference.
Synoptic earth mapping	Photography, observation, and acquisition of targets of opportunity.
Geological exploration and mapping (radar as a remote sensor of planetary surfaces)	Checkout, calibration, and some component replacement or repair; monitor and follow or adjust predetermined programs of experimentation; maintain logs. A crew of two or more men should include one with extensive background in electronics and with thorough knowledge of the radar to be used. An instrumentation background is also required. Film handling; change operating frequency of the radar as required.
Communication and navigation/traffic control	
Measurement of radio-frequency radiation	Switching, adjusting, calibrating, and checking the operation of equipment; monitor and observe.
Wide bandwidth transmission in space (communications)	Monitoring parameters and transmitting information to the ground station, selecting signals, verifying reception, interpreting results, analyzing faults, correcting minor difficulties.
Subsystems	
Specialists in each subsystem area will be required. Possibly some cross training would be advantageous.	

TABLE VI. - EXPERIMENT CREW FUNCTIONS - Concluded

Function	Requisite skills and/or background
Miscellaneous	
Onboard guidance and navigations systems performance assessment	Basic navigation, knowledge of celestial sphere and star identification, correlation of telescope sightings with charts, working knowledge of astrodynamics, general knowledge of digital computers and inertial sensors, operate equipment and interpret data.
EVA operations (limited)	High degree of mechanical skill, perform and monitor assembly experiments, pretraining in maintenance prodecures.
Space operations (orbital maneuvering and docking)	Normal astronaut skills and additional training in sensor operation and evaluation and docking operations; functions as a sensor and control servo.
Communications and tracking	Ability to course rendezvous with passive target in space and ability to operate manually aimed still and motion-picture cameras.

TABLE VII. - EXPERIMENT DUTY ASSIGNMENTS (GENERAL)

Area of knowledge	Crew skills	Special skills
Earth resources laboratory		
Agriculture, geology, geography	Physical scientist (two required)	Physical geologist and photogeologist
Oceanography	Physical scientist	Oceanographer
Biosciences laboratory		
Biology, microbiology, chemistry	Biologist (two required)	Biochemist, biological technician, and micro-biological technician
Physical sciences laboratory		
Electricity, mechanics, thermodynamics	Electromechanical engineer	General electromechanical technician, mechanical technician (engineer), thermodynamicist
Electronics (comm., radar, laser, antennas)	Electronics engineer	Microwave specialist (comm./radar)
Physics, chemistry, nuclear engineering	Physicist/chemist	Physicist and nuclear physicist
Optics	Optical physicist	Optical scientist, optical technician, photographic technician/cartographer

TABLE VIII. - EXPERIMENT DUTY ASSIGNMENTS

(SPECIFIC EXPERIMENTS)

Experiment	Crew skills	Special skills	No. of crewmen required
Bioscience[a]			
Genetics effect in microorganisms DNA recombination-mutation rate phage production	Biologist	Microbiological technician	2
Effect of drugs on mammalian behavior	Biologist/biochemist	None	1
Effect of zero gravity on sub-cellular level	Biologist/biological technician	None	1
Origin of biochemical compounds	Biologist/biochemist	None	2
Changes in sex distribution of offspring (rats) conceived in the weightless state	Biologist/biological technician	None	2
Physical sciences[b]			
Study of magnetic field lines, magnetics	Electromech. engr.	Electromech. tech. (general)	1
Crystallization studies (physical sciences/thermodynamics)	Electromech. engr.	Thermodynamicist	1
Ultraviolet to soft X-ray spectroscopy	Physicist/chemist	Physicist	1
Nuclear emulsion	Physicist/chemist	Nuclear physicist	1
Daytime sodium cloud	Optical physicist	Photo. tech./ cartographer	1
Airglow spectrometry	Optical physicist	Optical scientist	1

[a]Crew monitoring interval typically continuous.

[b]Crew monitoring continuous and intermittent.

TABLE VIII. - EXPERIMENT DUTY ASSIGNMENTS

(SPECIFIC EXPERIMENTS) - Continued

Experiment	Crew skills	Special skills	No. of crewmen required
Bubbles in zero gravity	Electromech. engr.	Mech. tech. (engr.)	1
Day-night camera	Optical physicist	Optical tech.	1
Antenna pattern	Electronics engr.	Microwave spec. (comm./ radar)	1
Earth resources scientific technology[b]			
Agriculture/forestry			
Multispectral target (tracking telescope)	Physical scientist	Photogeologist	1
Synoptic earth mapping (multiband camera)	Physical scientist	Photogeologist	1
Multifrequency radar imagery (high-resolution radar imager)	Physical scientist	Physical geologist	1
Detail observation of earth surface (high-resolution panoramic camera)	Physical scientist	Physical geologist	1
Oceanography/marine technology			
Ocean observation (radar altimeter) (strong source of EMI)	Physical scientist	Oceanographer	1
Geology/hydrology			
Ultraviolet imager/ spectrometer	Physical scientist	Physical geologist	1

[b]Crew monitoring continuous and intermittent.

TABLE VIII. - EXPERIMENT DUTY ASSIGNMENTS

(SPECIFIC EXPERIMENTS) - Concluded

Experiment	Crew skills	Special skills	No. of crewmen required
Geography/cartography			
Observation of earth detail	Physical scientist	Physical geologist	1

TABLE IX. - BASIC CREW-TIME UTILIZATION

Events	Time, hr
Sleep period	8.0
Work period	8.0
Personal housekeeping[a]	1.5
Communal housekeeping[b]	0.5
Recreation period and exercise	3.0
Three eating periods	3.0
Total	24.0

[a]The time allowed for personal housekeeping is that which is estimated to be required in a 24-hour day and not necessarily performed in one block of time. Personal housekeeping includes such things as body-waste collection, body cleaning, grooming, and dressing and undressing.

[b]Communal duties such as house cleaning of galley and hygiene area are to be rotated among crewmembers for an agreed period of time.

TABLE X. - OPERATIONAL CREW FUNCTIONS

[Nominal inflight condition: man-hour schedule for 48-hour week]

Crewman position	Functions	Time	Duty cycle	Skills
1. Commander	a. Serves as navigator in command center	2 hrs (variable)	day	Astronaut/engineer, executive, navigator (basic), knowledge of navigation and astrodynamics, general knowledge of computer equipment
	b. Reviews operations log and schedule	1 hr	day	
	c. Evaluates operational problems	2 hrs (variable)	day	
	d. Inspects space base, directs drills	1 hr	day	
	e. Makes management decisions	2 hrs (variable)	day	
	f. Serves as chairman at executive staff meetings	3 to 4 hrs	week	
2. Deputy commander	a. to e. (same as crewman no. 1)	2 hrs (variable)	day	Astronaut/engineer, executive asst., navigator (knowledge same as crewman no. 1)
	f. Participates in executive staff meetings	6 hrs (variable)	day and week	
3. Flight surgeon	a. Manages and analyzes biomed. program	2 hrs (variable)	day	Biomedical scientist/M.D., surgeon
	b. Monitors crew medical condition	2 hrs (variable)	day	
	c. Serves as sick call physician	2 hrs (variable)	day	
	d. Provides crew medical treatment	2 hrs (variable)	day	
	e. Participates in executive staff meetings	3 to 4 hrs	week	
4. Systems manager	a. Manages, evaluates, plans, and analyzes systems	2 hrs (variable)	day	Systems engr. - basic systems management background, assess system operation, programing
	b. Inspects DMS lab and maintenance shop	2 hrs (variable)	day	
	c. Performs command-center duties	2 hrs (variable)	day	
	d. Controls subsystem equipment	2 hrs (variable)	day	
	e. Participates in executive staff meetings	3 to 4 hrs	week	
5. Technical director	a. Manages technical projects; evaluates, plans, makes experiment program decisions and handles related data-acquisition problems	3 hrs (variable)	day	Physical scientist - basic overall scientific research management background
	b. Performs command-center duties	4 hrs (variable)	day	
	c. Controls experiment equipment	1 hr	day	
	d. Participates in executive staff meetings	3 to 4 hrs	week	
6. Operations and logistics control manager	a. Manages supply group	2.5 hrs (variable)	day	Engineer/manager - basic knowledge of logistics/supply operations; general knowledge of food control and distribution
	b. Inspects officers mess, crew cafeteria and quarters, hygienic areas, and storeroom	1.5 hrs (variable)		
	c. Analyzes operational problems	1 hr	day	
	d. Oversees food preparation and serving	3 hrs (intermittent)	day	
	e. Participates in executive staff meetings	3 to 4 hrs	week	
7. Power systems officer	a. Serves as systems monitor/controller in command center	4 hrs (continuous)	day	Chemist, nuclear physicist, electronics systems management background
	b. Performs power systems housekeeping duties	2 hrs (variable)	day	
	c. Controls and manages power systems	2 hrs (variable)	day	
8. Communications officer	a. Handles base intracommunications and communications to earth	4 hrs (continuous)	day	Electronics engr. (instrumentation), public affairs office experience
	b. Manages communications: related subsystems, OCS, audio/video closed circuit; evaluates, interprets, reprograms, makes decisions, plans, schedules	4 hrs (intermittent)	day	
9. Data management system officer	a. Performs DMS lab duties, monitors incoming data, transmits data to earth, stores data	4 hrs (continuous)	day (standby duty)	Engineer/programer - basic knowledge of DMS, computer analysis/programing background, electronics
	b. Performs DMS management duties: analyzes and edits data; selects, filtrates, or rejects data; controls tape recorders	4 hrs (intermittent)	day	
10. Data processing analyst	a. Performs DMS lab duties, monitors, transmits to earth, and stores data	4 hrs (intermittent)	day	Analyst/mathematician
	b. Reduces data, dumps housekeeping data, dumps experiment data, dumps raw data, dumps processed data, changes data program, controls and schedules, serves as math aide	4 hrs (intermittent)	day	

TABLE X. - OPERATIONAL CREW FUNCTIONS - Continued

[Nominal inflight condition; man-hour schedule for 48-hour week]

Crewman position	Functions	Time	Duty cycle	Skills
11. Computer specialist/ programer	a. Performs DMS lab duties, monitors, transmits to earth, and stores data b. Performs same functions as crewmen nos. 9 and 10; acts as math aide; analyzes onboard data, program changes, etc.	4 hrs (intermittent) 4 hrs (intermittent)	day	DMS assistant
12. Systems monitor/ controller	a. Serves as monitor/controller: monitors caution and warning system and subsystems, observes OCS display; communicates (video and audio); calibrates, checks, adjusts, interprets, observes, and evaluates systems as required	4 hrs on, 4 hrs off, 4 hrs on	day	Electromech. engr.
13. Systems monitor/ controller	a. Performs same functions as crewman no. 12; serves as communicator	4 hrs on, 4 hrs off, 4 hrs on	day	Instrument engr.
14. Systems monitor/ controller	a. Performs same functions as crewman no. 12; serves as space and ground communicator	4 hrs on, 4 hrs off, 4 hrs on	day	Systems engr.
15. Systems monitor/ controller	a. Performs same functions as crewman no. 12; performs systems housekeeping monitoring duties	4 hrs on, 4 hrs off, 4 hrs on	day	Electrical and nuclear engr.
16. Communications specialist	a. Performs command-center duty as communicator b. Inspects, services, and adjusts all communication equipment on board c. Maintains effective communications by daily scheduled preventive maintenance as required	2 hrs (variable) 4 hrs (intermittent) 2 hrs (variable)	day day day	Electronics technician - antenna, radar, laser, TV, audio experience, etc.
17. Electronics technician	a. Performs maintenance shop duties (4-hr shift); tests, calibrates, replaces, repairs, and modifies electronic equipment b. Inspects space base daily (4 hrs, intermittently); performs scheduled preventive maintenance as required	4 hrs on, 4 hrs off, 4 hrs on	day	Maintenance/electronics technician - digital and analog computers, inertial guidance, solid-state-circuit background
18. Maintenance engr./safety officer	a. Performs planning and scheduling duties and maintenance and safety duties, maintains reporting system b. Manages maintenance shop c. Serves as safety officer, maintains, inspects	2 hrs (variable) 4 hrs (variable) 2 hrs (variable)	day day day	Maintenance engr./safety officer, astronautics engr. - electromechanical background
19. Metallurgist/ welding engr.	a. Manages space mfg. chamber, analyzes, tests, develops mfg. processes and welding techniques b. Performs maintenance shop duties: management, welding, M&R, manufacturing/modifications	4 hrs 4 hrs	day day	Metallurgist/welding engr.
20. Optical technician	a. Performs instrument lab duties; acts as lab bench technician; checks out, calibrates, adjusts, and modifies b. Performs maintenance shop duties and general shop-work duties c. Performs astronomy lab duties, removes and replaces, adjusts, and calibrates, as required	5 hrs (variable) 2 hrs (variable) 1 hr (variable)	day day	Optical lab bench
21. Mechanical technician	a. Performs maintenance shop duties as technician/repairman for inflight checkout and general maintenance and modification tasks, operates all shop-type equipment b. Performs scheduled daily preventative maintenance duties, paints and cleans up space base as required	6 hrs (intermittent) 2 hrs (variable)	day day	Mechanical technician - general shop skills

TABLE X. - OPERATIONAL CREW FUNCTIONS - Continued

[Nominal inflight condition: man-hour schedule for 48-hour week]

Crewman position	Functions	Time	Duty cycle	Skills
22. Machinist/ welder technician	a. Performs maintenance shop duties as machinist, operates machine and general shop equipment, welds, fabricates, assembles, paints b. Serves as lab asst. in space mfg. chamber, welds, performs mfg. processes and test setup	6 hrs (variable) 2 hrs (variable)	day day	General machinist/welder - overall skills background
23. Instrument technician	a. Performs instrument lab duties: instrument replacement, repair, calibration, check, and modifications: acts as instrument operator b. Performs maintenance shop duties, general instrument maintenance and same functions as crewman no. 22	4 hrs (variable) 4 hrs (variable)	day day	Instr. shop machinist, electromech. background
24. Management analyst/ weights engineer	a. Serves as space-base administrative engr.: programs daily operations, planning and scheduling, manpower allocation, and time and motion studies, inspects crew community housekeeping b. Serves as space-base weights engr., handles weight control and c.g. problems of expanding space base, ballast problems, analysis	6 hrs (variable) 2 hrs (variable)	day day	Manager/engr., weights engineering background, operations engineering
25. Physical conditioning supervisor/ management technician	a. Performs gymnasium duties: monitors crew physical condition and weight control, performs therapy b. Serves as operations flight clerk: types management directives and schedules, maintains documentary log; performs clerical and technical writing tasks	6 hrs (variable) 2 hrs (variable)	day day	Physical director, group-exercise/weight-control (diet) background
26. Logistics specialist/ storekeeper	a. Serves as space-base logistics specialist: supply control survey, record keeping, inventory, order expediting (4-hr duty) b. Serves as storekeeper (4-hr duty) and supply-room attendant for crew supplies and control of spare parts	4 hrs on, 4 hrs off, 4 hrs on	day	Supply background
27. Station systems housekeeping supervisor	a. Serves as space-base preventive maintenance serviceman: monitors and services the power distribution and ECS systems, humidity checks, fuel-cell purges, LiOH cartridge changes, debris-trap changes, etc.	8 hrs (intermittent)	day	Electromechanical technician
28. First cook	a. Performs kitchen duties: preparation, meal scheduling, and menu planning, cleanup: acts as nutritionist, supervises cook and mess attendants (3 meals/day, 6 servings/day)	8 hrs (intermittent)	day	Chef, nutritionist, food management specialist
29. Second cook	a. Performs kitchen duties, primarily the same as first cook	8 hrs (intermittent)	day	Cook, kitchen helper
30. Officers' mess attendant	a. Serves food in officers' mess, serves on cleanup detail, assists in food preparation as required b. Serves in supply room and as intercom phone talker at command center as required	6 hrs (intermittent) 2 hrs (variable)	day day	Waiter, cook, kitchen helper
31. Cafeteria mess attendant	a. Serves food in crew cafeteria: performs other duties similar to officers' mess attendant	6 hrs (intermittent) 2 hrs (variable)	day	Waiter, cook, kitchen helper
32. Officers' steward	a. Serves as officers' valet b. Cleans rooms (including restroom) for executive staff and senior scientists	8 hrs (variable)	day	Housekeeper, sanitary engineer

TABLE X. - OPERATIONAL CREW FUNCTIONS - Concluded

[Nominal inflight condition; man-hour schedule for 48-hour week]

Crewman position	Functions	Time	Duty cycle	Skills
33. Guidance and control manager	a. Performs command-center console operator duties (navigation): maneuvering, docking, control of other space vehicles, monitoring of direct control systems	4 hrs on, 4 hrs off, 4 hrs on	day	Navigator/astronaut engineer
34. Navigator	a. Serves as command-center console-control operator (navigation); performs same duties as crewman no. 33	4 hrs on, 4 hrs off, 4 hrs on	day	Navigator/astronaut engineer
35. Assistant navigator	a. Serves as command-center console-control operator (navigation); performs same duties as crewman no. 33	4 hrs on, 4 hrs off, 4 hrs on	day	Navigator/astronaut engineer
36. Janitor	a. Performs space-base janitorial duties on a scheduled basis: washes floors and port windows, dusts and vacuums, collects and processes trash, cleans restrooms, changes lighting fixtures, performs minor maintenance, etc.	8 hrs (continuous)	day	Janitor, housekeeper

TABLE XI. - CREW DUTY CYCLES

[Nominal workday for 60 crewman]

Department	Type of position	Number of crewmen				
		8 hrs continuous	8 hrs intermittent	4 hrs variable, 4 hrs intermittent	8 hrs variable	4 hrs on, 4 hrs off, 4 hrs on
Executive staff	Commander, dep. comdr., systems mgr., tech. director				4	
	Flight surgeon, OLC mgr.			2		
Telecommunications Group	Comm., DMS, and pwr. sys. officers, electronics technician			4		
	DP analyst, programer		2			
	Sys. mon./conts.					4
Systems Management Group	Sys. hskp. sup.		1			
	Maint. engr./safety, met./weld. engr., and 2 maint. techs.				4	
Supply Group	2 cooks, 2 mess attendants		4			
	2 stewards				2	
	Mgt. analyst, storekeeper	2				
Navigation Group	G&C officer, navigators					3
Technical Projects Dept.	Experimenters	17				
	Experiment support personnel				6	
	Biomed. officer personnel			5		
Totals		19	7	11	16	7

TABLE XII. - CREW COMPOSITION

Position	Duty title	Abbreviated form
	Executive staff (six crewmen)	
1	Commander	Comdr.
2	Deputy commander	Dep. comdr.
3	Flight surgeon	None
4	Technical director	Technical dir.
5	Systems manager	Sys. mgr.
6	Operations and logistics control manager	OLC mgr.
	Operations Department (26 crewmen)	
7	Power systems officer	Pwr. sys. officer
8	Communications officer	Comm. officer
9	Data management system officer	DMS officer
10	Maintenance engineer/safety officer	Maint. engr./safety
11	Metallurgist/welding engineer	Met./weld. engr.
12	Management analyst/weights engineer	Mgt. analyst/wts.
13	Physical director/management technician	Phys. dir.
14	Data processing analyst	DP analyst
15	Computer specialist/programer	Programer
16	Station systems housekeeping supervisor	Sys. hskp. sup.
17	Instrument technician	Instr. tech.
18	Machinist/welder technician	Mach./weld. tech.
19	Systems monitor/controller A (electro-mechanical engineer)	Sys. mon./cont. A
20	Systems monitor/controller B (instrument engineer)	Sys. mon./cont. B
21	Systems monitor/controller C (systems engineer)	Sys. mon./cont. C
22	Systems monitor/controller D (electrical/nuclear engineer)	Sys. mon./cont. D
23	Guidance and control officer	G&C officer
24	Navigator	None

TABLE XII. - CREW COMPOSITION - Continued

Position	Duty title	Abbreviated form
Operations Department (26 crewmen)		
25	Assistant navigator	Asst. navigator
26	Logistics supply specialist/storekeeper	Log. spec.
27	Electronics technician	Elec. tech.
28	Station's first cook	First cook
29	Station's second cook	Second cook
30	Officers' mess attendant	Off. mess att.
31	Cafeteria mess attendant	Cafe. mess att.
32	Officers' steward	Off. steward
Technical Projects Department (28 crewmen)		
33	Cartographer	None
34	Meteorologist	None
35	Geodesist	None
36	Oceanographer	None
37	Experimental investigator (geology)	EI (geology)
38	Experimental investigator (meteorology)	EI (meteorology)
39	Traffic control observer	Tfc. cont. obs.
40	Biologist	None
41	Biochemist	None
42	Microbiologist	None
43	Laboratory technologist (biology)	Lab tech. (biology)
44	Laboratory technologist (biochemistry)	Lab tech. (biochem.)
45	Zoologist	None
46	Biotechnologist (M. D.)	None
47	Veterinarian	None
48	Biomedical scientist (M. D.)	Biomed. scientist
49	Neurologist	None
50	Physiologist	None

TABLE XII. - CREW COMPOSITION - Concluded

Position	Duty title	Abbreviated form
Technical Projects Department (28 crewmen)		
51	Psychiatrist/chaplain	Psych./chaplain
52	Medical technician	Med. tech.
53	Astronomer A	None
54	Astronomer B	None
55	Assistant astronomer	Asst. astronomer
56	Physicist/chemist	None
57	Mathematician/geodesist	Math./geod.
58	Test engineer	None
59	Journalist/photographer	Journ./photog.
60	Photographic technician	Photo. tech.

TABLE XIII. - SIXTY-CREWMAN COMPARTMENT ALLOCATION

Single compartments	Double compartments	Quadruple compartments
First deck		
Commander Flight surgeon	2 crewmen — Astronomer A, Cartographer 2 crewmen — Astronomer B, Zoologist	4 crewmen — Opns. engr. A, Opns. engr. B, Maint. engr., Test engr. 4 crewmen — Power systems officer, G&C officer, DMS officer, Mgt. analyst
Second deck		
Deputy commander Technical director	2 crewmen — Biologist, Meteorologist 2 crewmen — Biochemist, Geodesist 2 crewmen — Biomed. scientist, Biotechnologist	4 crewmen — Neurologist, Physiologist, Journalist/photographer, Physical therapist 4 crewmen — Navigator, Asst. navigator, Welding engr., DP analyst
Third deck		
Systems manager Operations and logistics control manager	(No double compartments on third deck)	4 crewmen — EI (geology), EI (oceanography), Sys. hskp. sup., Control console operator 4 crewmen — Computer programer, Math./geodesist, Lab tech. (biology), Lab tech. (biochemistry) 4 crewmen — Assist. astronomer, Veterinarian, Traffic control observer, Systems monitor/controller
Fourth deck		
(No single compartments on fourth deck)	2 crewmen — Microbiologist, Physicist/chemist 2 crewmen — Oceanographer, Comm. officer	4 crewmen — 1st cook, 2nd cook, Mess attendant, Mess attendant 4 crewmen — Mach./weld. tech., Electronics technician, Instrument technician, Chemical technician 4 crewmen — Storekeeper, Officers steward, Medical technician, Officers' steward/barber

TABLE XIV. - TYPICAL CREW DISTRIBUTION

[Nominal inflight work/rest period]

Work/rest cycles		Time (24-hour day)					
		Hub modules		Artificial-gravity modules		Nuclear power substations	
Crewmen	Events	No. 1	No. 2	AGM 1	AGM 2	NP 1	NP 2
1. Commander	Sleep			8			
	Off duty			5	3		
	Work	1	1	4	1	0.5	0.5
2. Flight surgeon	Sleep			8			
	Off duty			5	3		
	Work	2	2	4			
3. Navigator	Sleep				8		
	Off duty			3	5		
	Work			8			
4. Astronomer	Sleep			8			
	Off duty			5	3		
	Work		8				
5. Biologist	Sleep				8		
	Off duty			5	3		
	Work	8					
6. First cook	Sleep				8		
	Off duty			3	5		
	Work			8			
7. Power systems officer	Sleep			8			
	Off duty			5	3		
	Work	1	1	4		1	1
8. Maint. engr./ safety officer	Sleep			8			
	Off duty			5	3		
	Work	1	1	1	4	0.5	0.5

TABLE XIV. - TYPICAL CREW DISTRIBUTION - Concluded

[Nominal inflight work/rest period]

Work/rest cycles		Time (24-hour day)					
		Hub modules		Artificial-gravity modules		Nuclear power substations	
Crewmen	Events	No. 1	No. 2	AGM 1	AGM 2	NP 1	NP 2
9. Console control monitor/ operator	Sleep				8		
	Off duty			3	5		
	Work			8			
10. Electronics technician (maintenance)	Sleep				8		
	Off duty			3	5		
	Work	1	1	1	4	0.5	0.5
Totals.		14	14	120	87	2.5	2.5

TABLE XV. - SPACE-BASE CREW DISTRIBUTION[a]

Crewmen on board	Hub module 1			Hub module 2			Living quarters					
							AGM 1			AGM 2		
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
12	-	-	-	-	-	-	12	12	12	-	-	-
24	6	10	1	-	-	-	18	23	14	-	-	-
30	6	16	1	-	-	-	13	14	5	11	15	9
40	4	11	1	3	7	2	16	18	7	17	19	15
50	5	10	1	4	10	3	18	21	10	23	25	20
60	6	15	1	5	15	5	20	22	10	29	32	20

[a]Estimated maximum of two crewmen with no minimum requirements in each nuclear power substation.

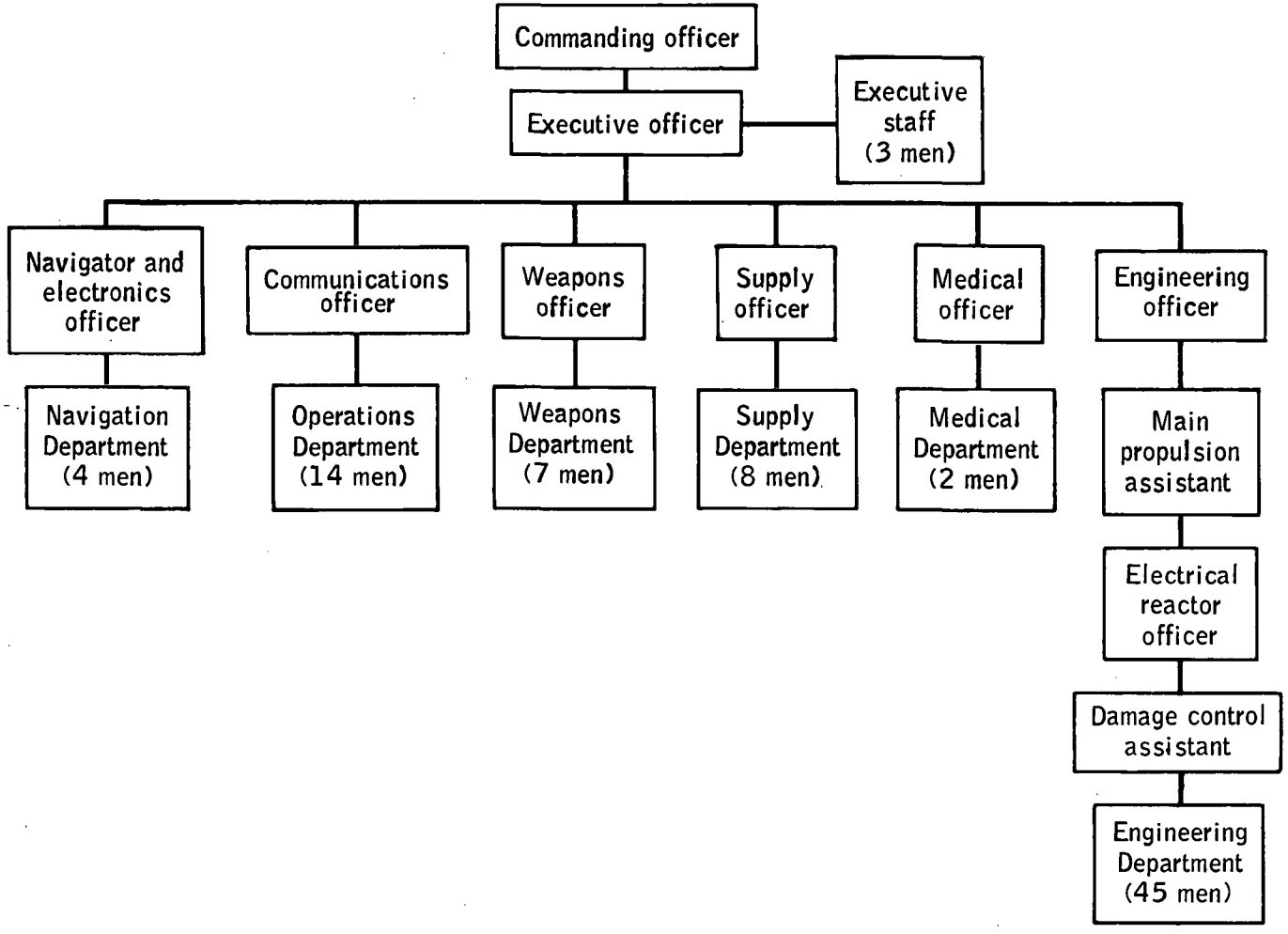


Figure 1.- Typical USN nuclear submarine organization (crew complement of 94 men).

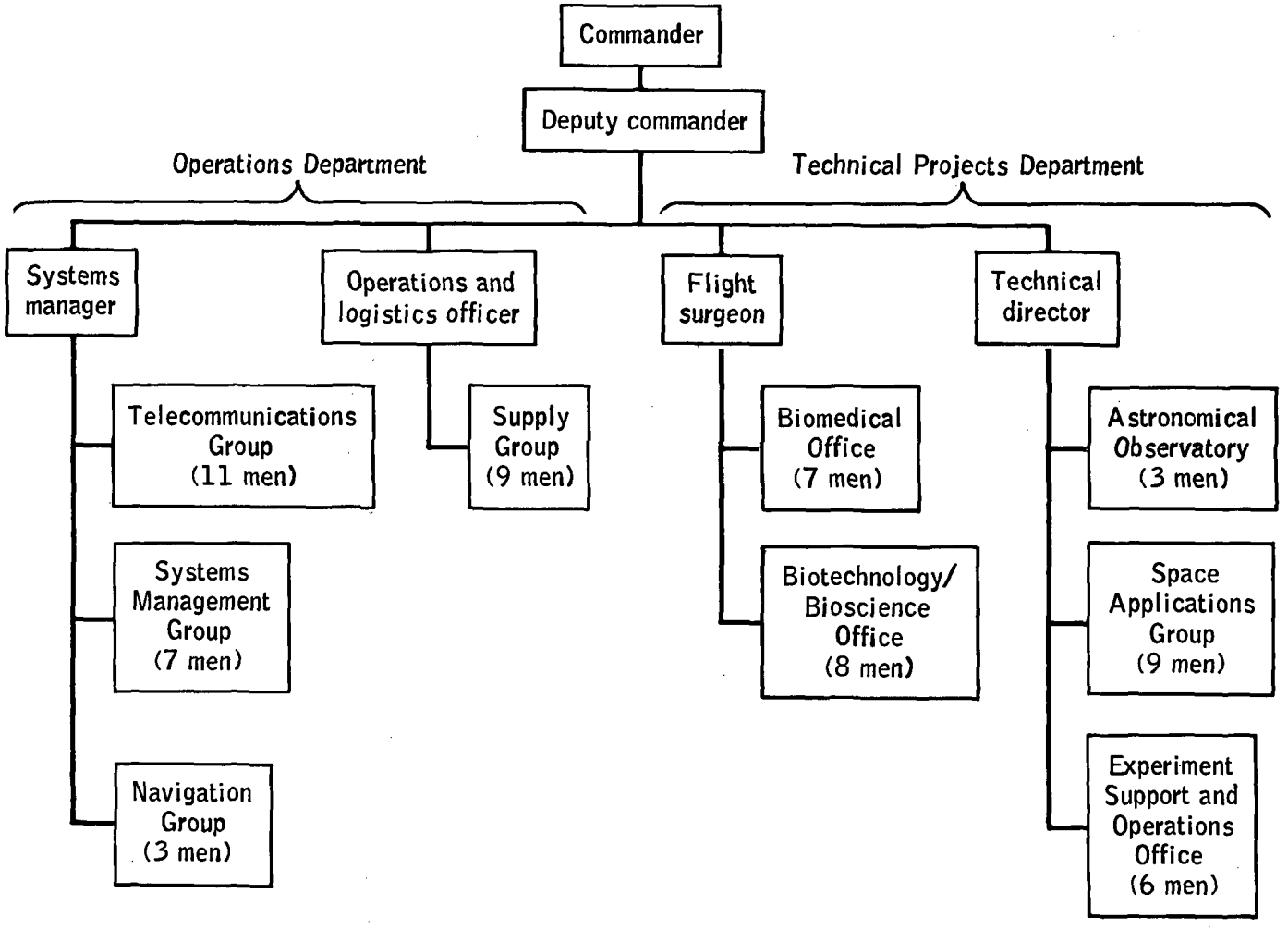


Figure 2.- Space-base organization (crew complement of 69 men).

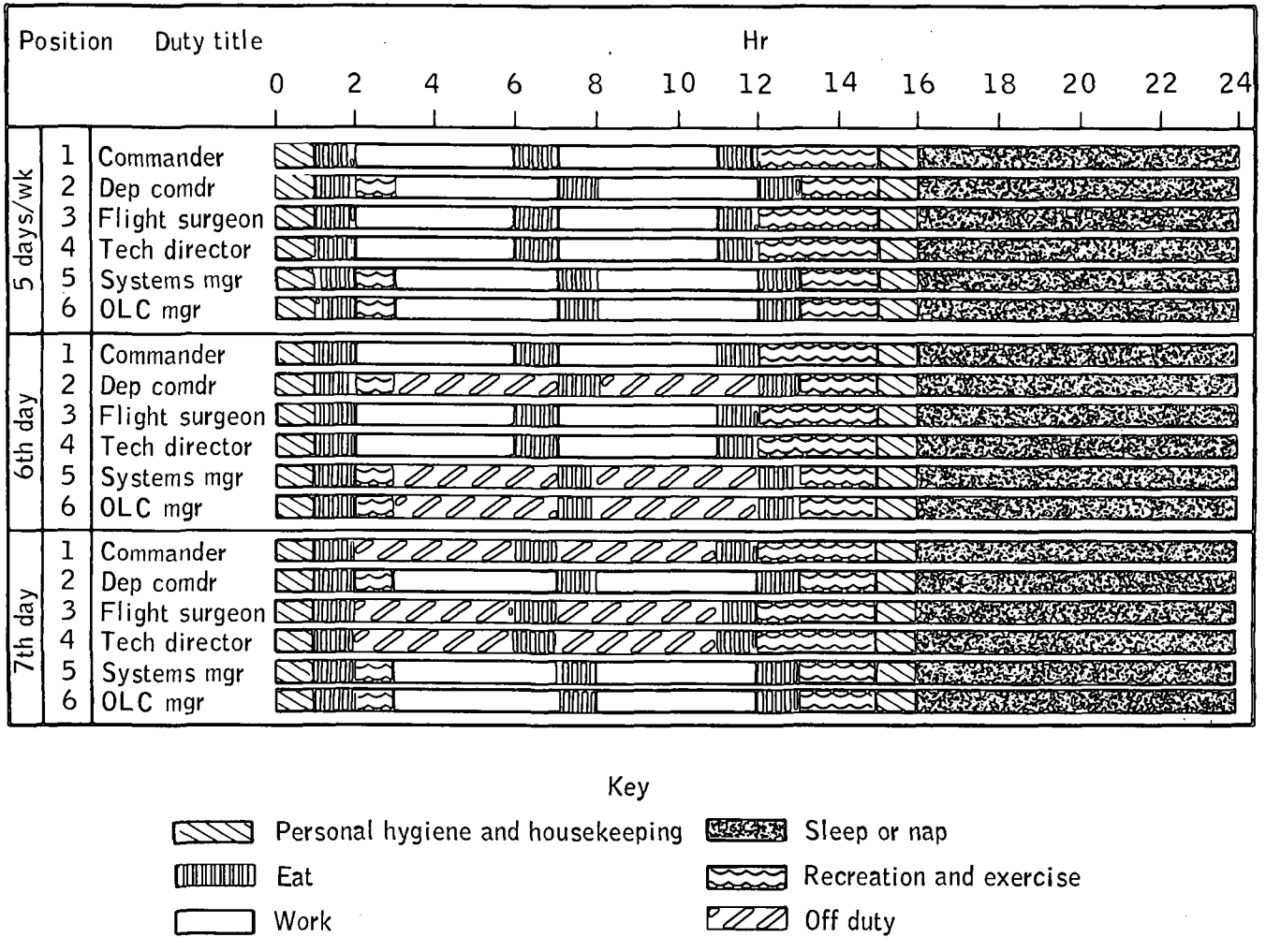
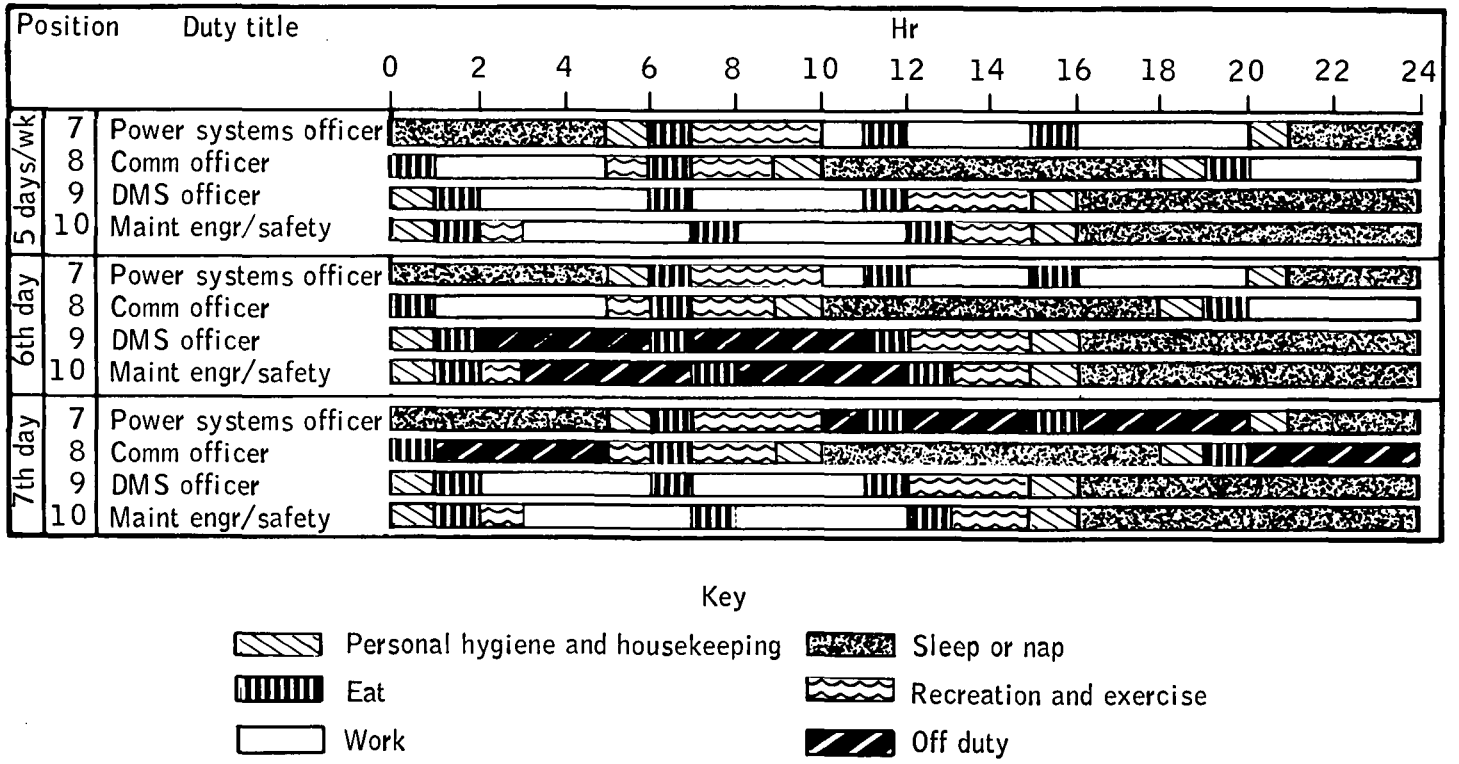
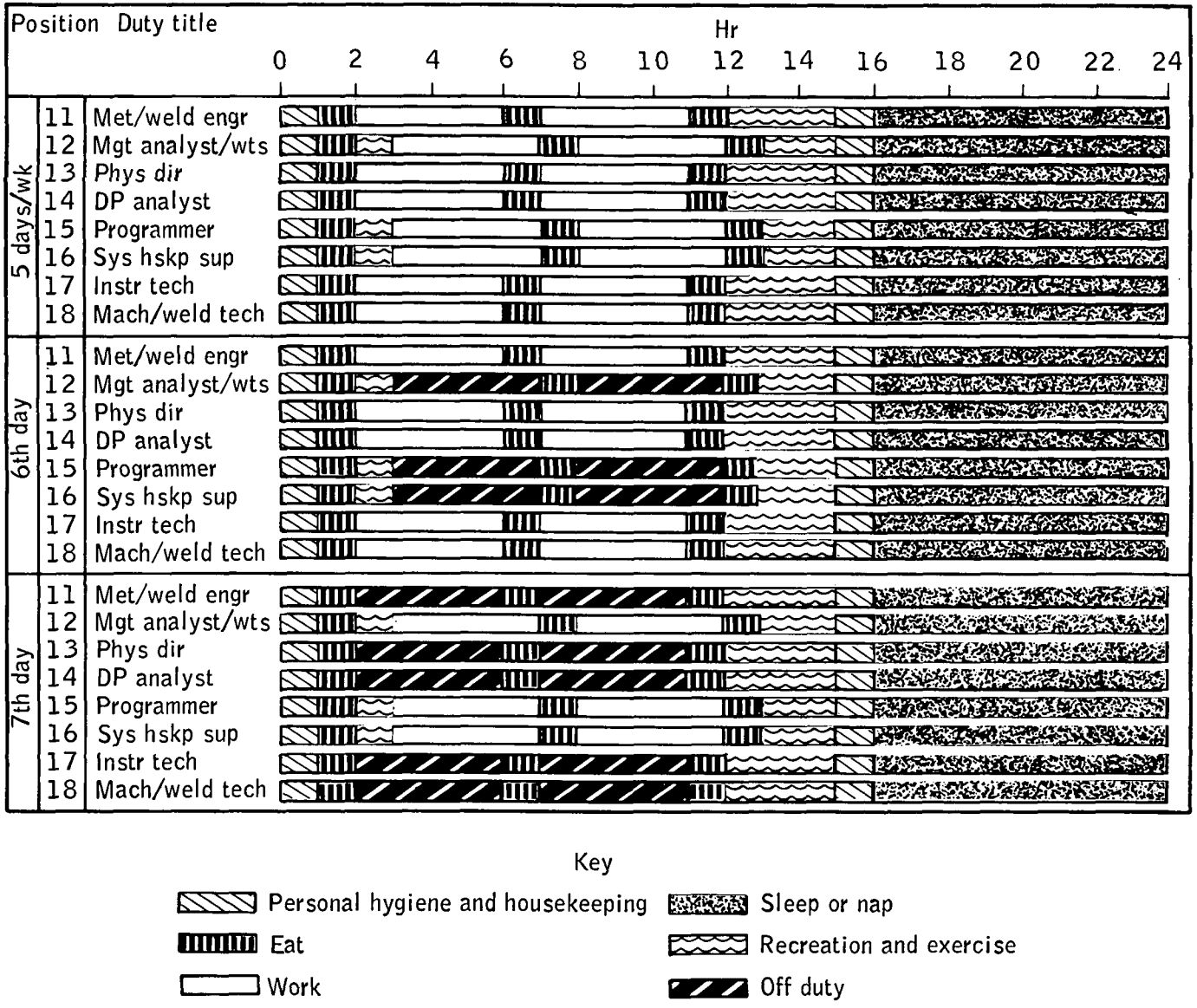


Figure 3.- Executive staff weekly crew schedule (nominal inflight work period).



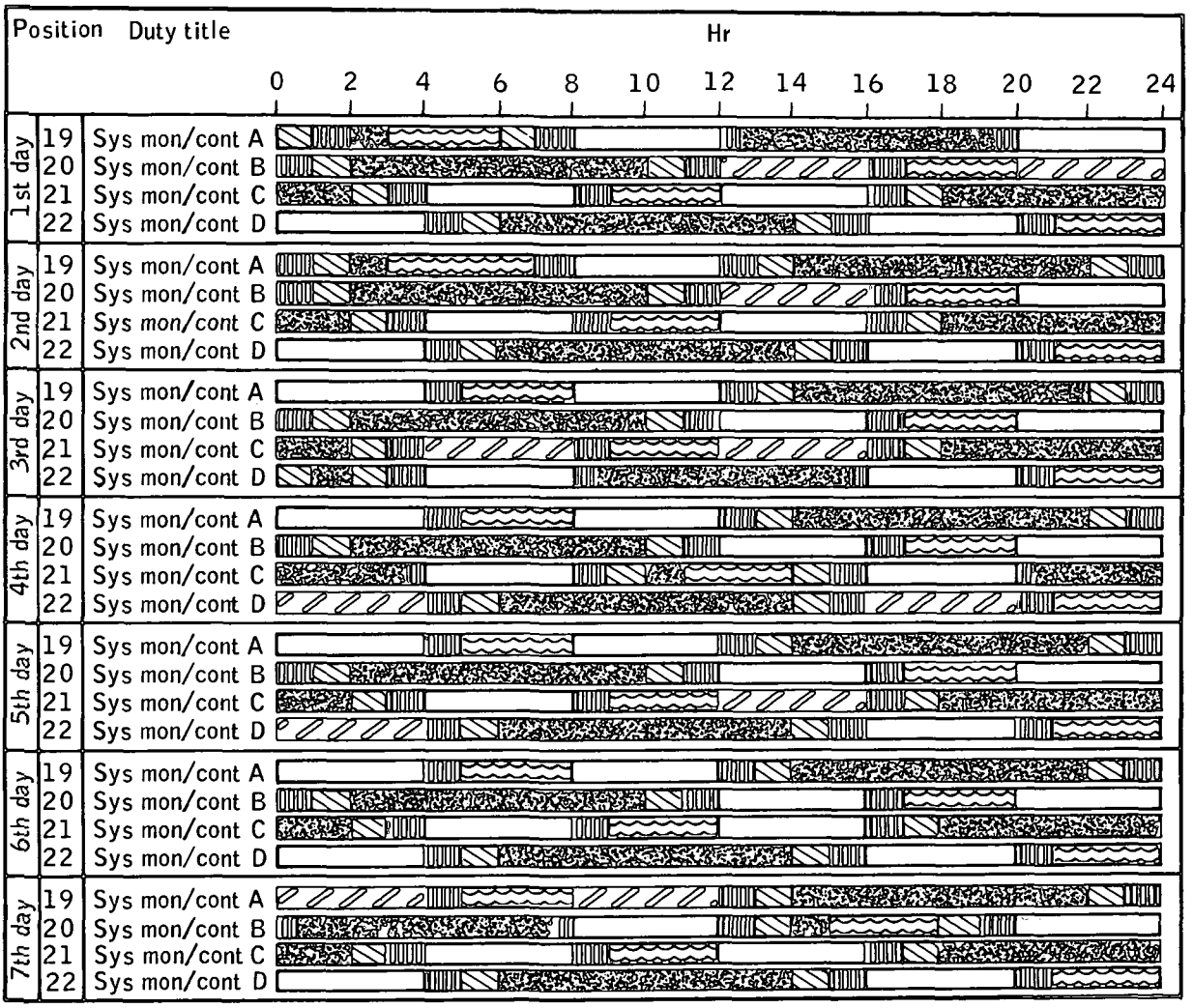
(a) Crew positions 7 to 10.

Figure 4.- Operations Department weekly crew schedule (nominal inflight work period).



(b) Crew positions 11 to 18.

Figure 4.- Continued.

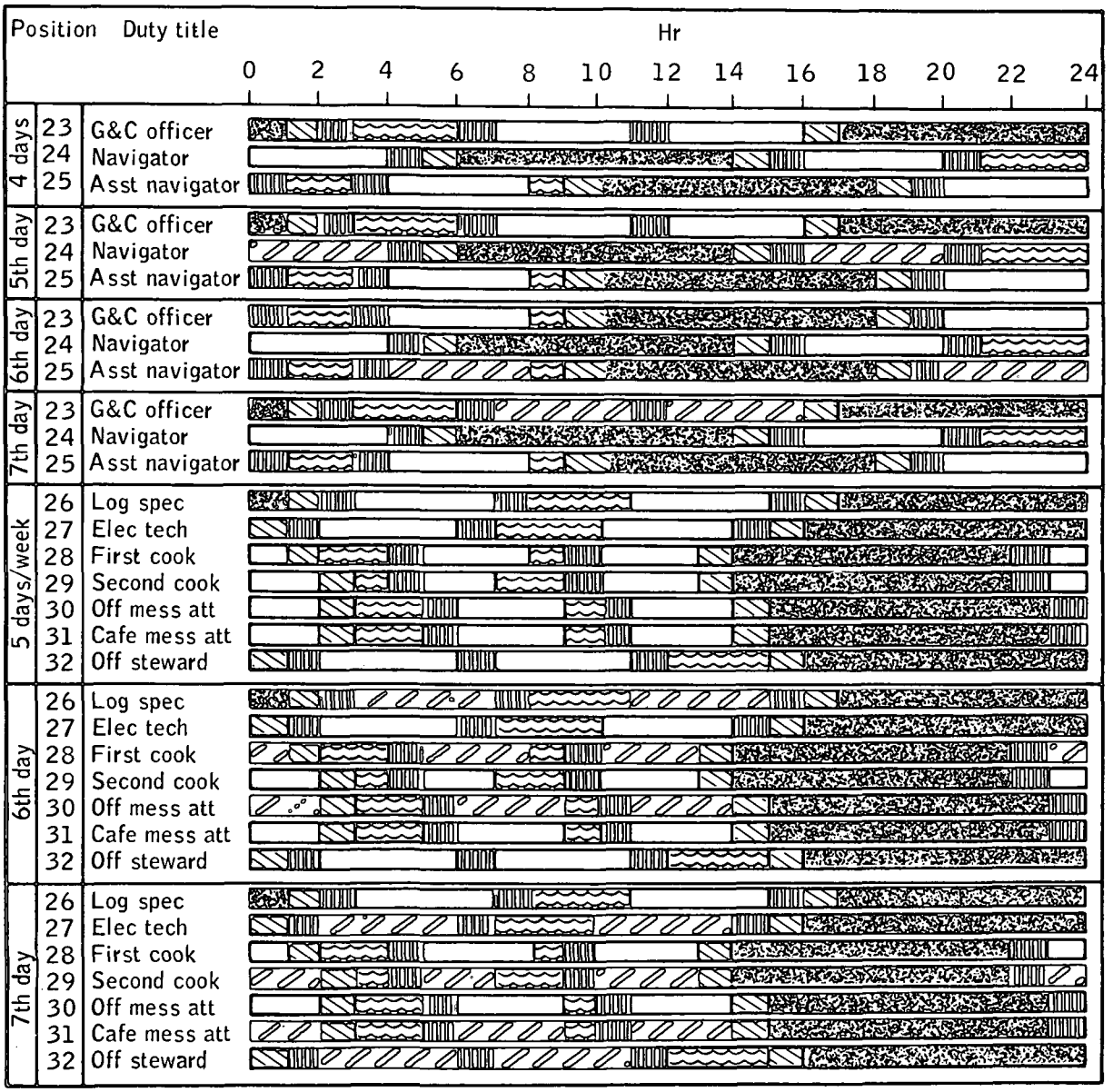


Key

- Personal hygiene and housekeeping
- Eat
- Work
- Sleep or nap
- Recreation and exercise
- Off duty

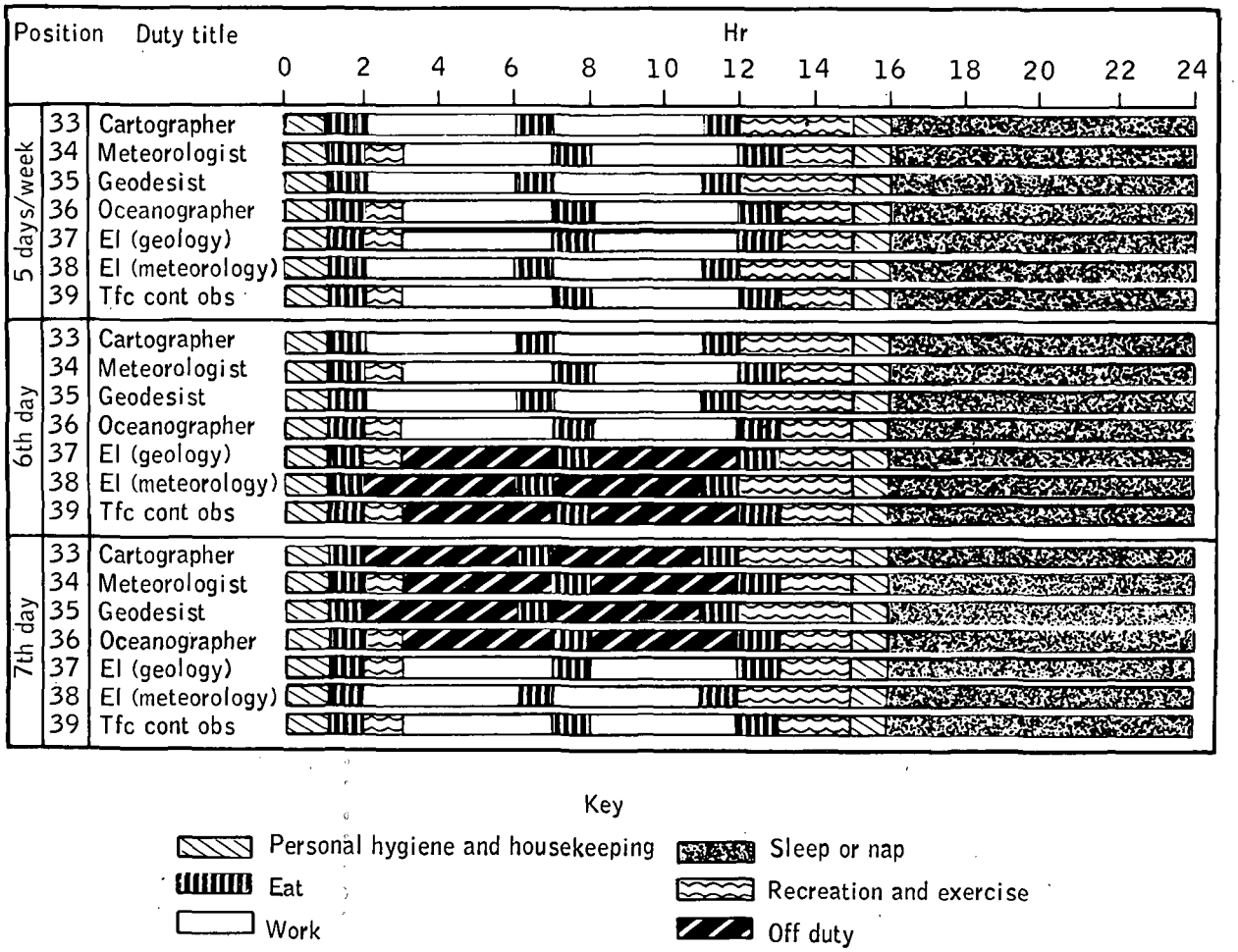
(c) Systems monitors/controllers (crew positions 19 to 22).

Figure 4.- Continued.



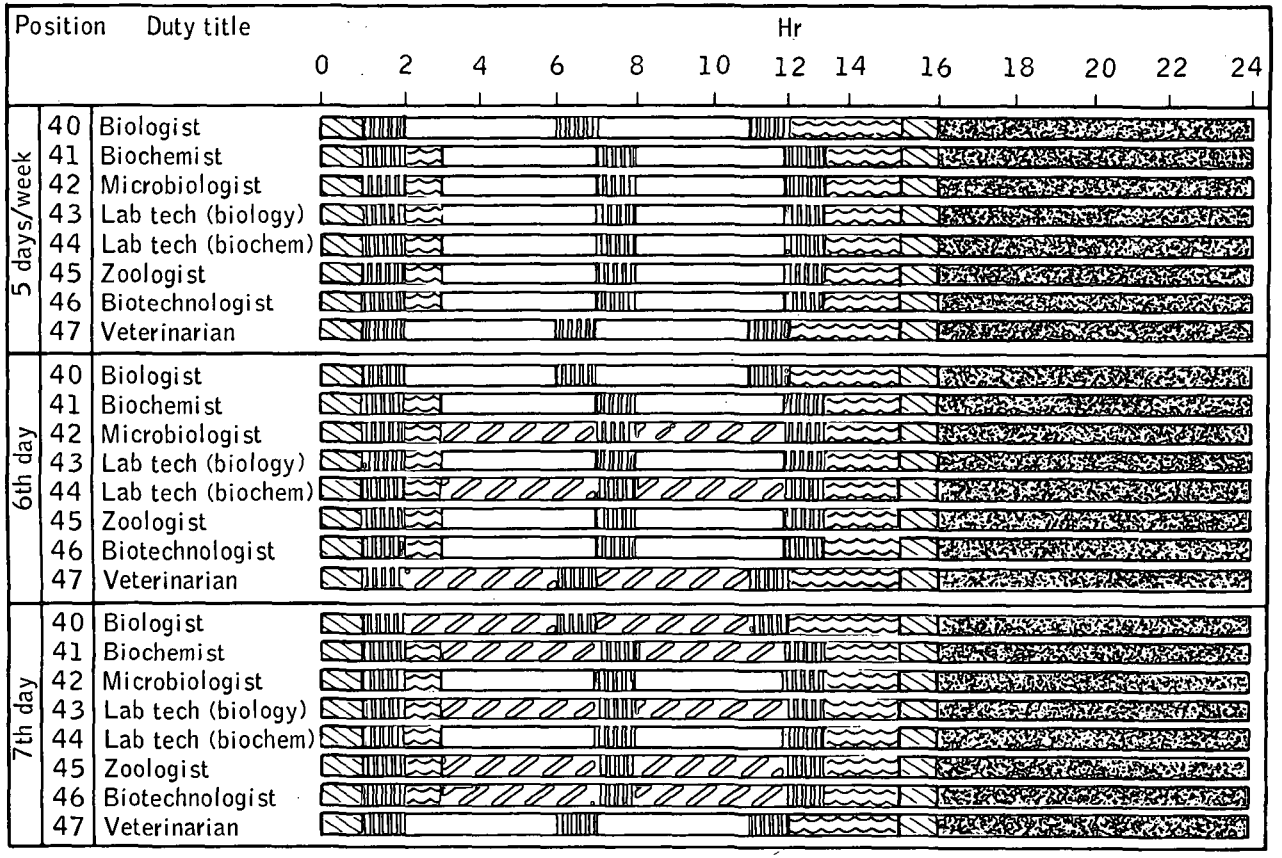
(d) Crew positions 23 to 32.

Figure 4.- Concluded.



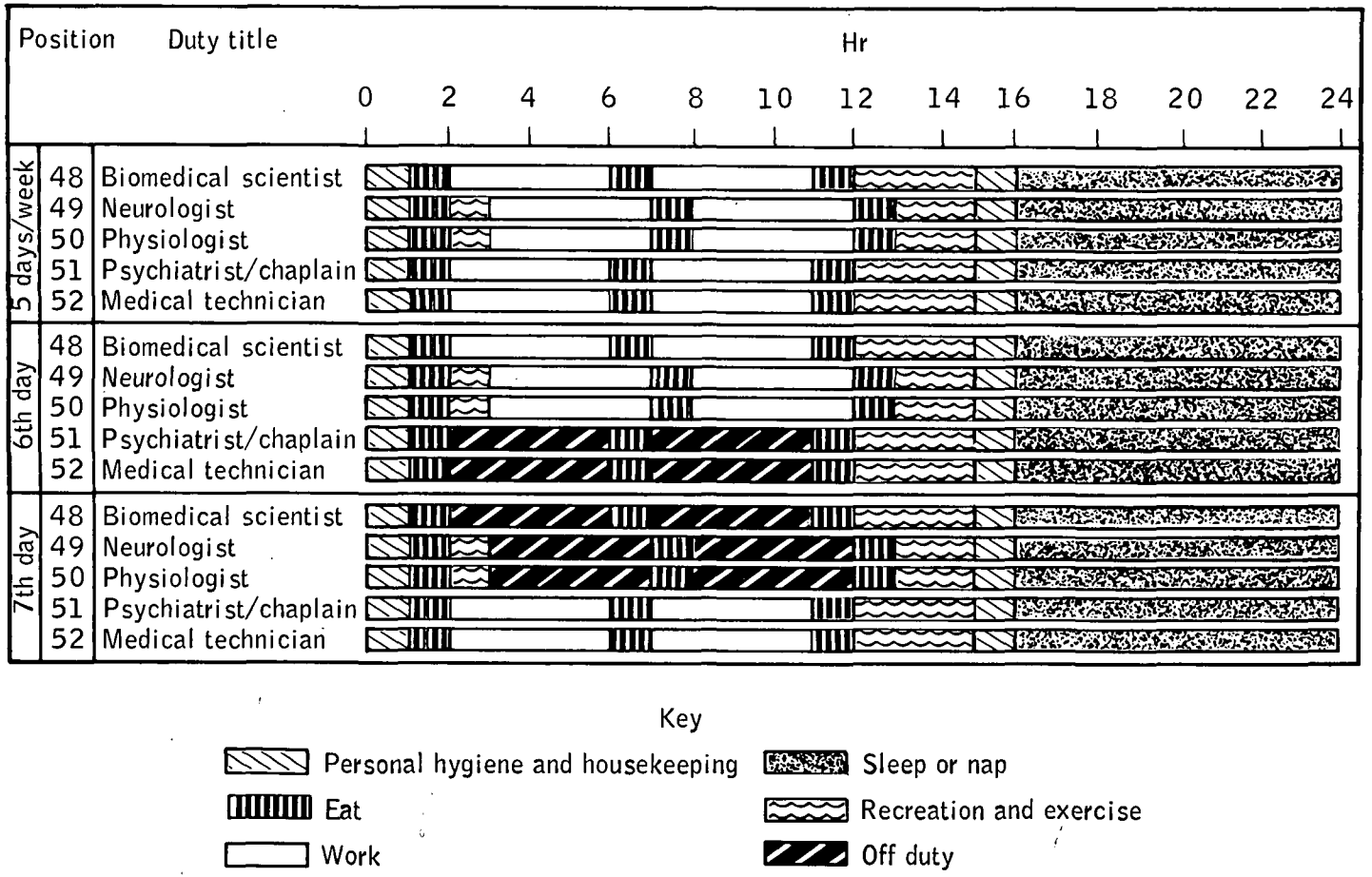
(a) Crew positions 33 to 39.

Figure 5. - Technical Projects Department weekly crew schedule (nominal inflight work period).



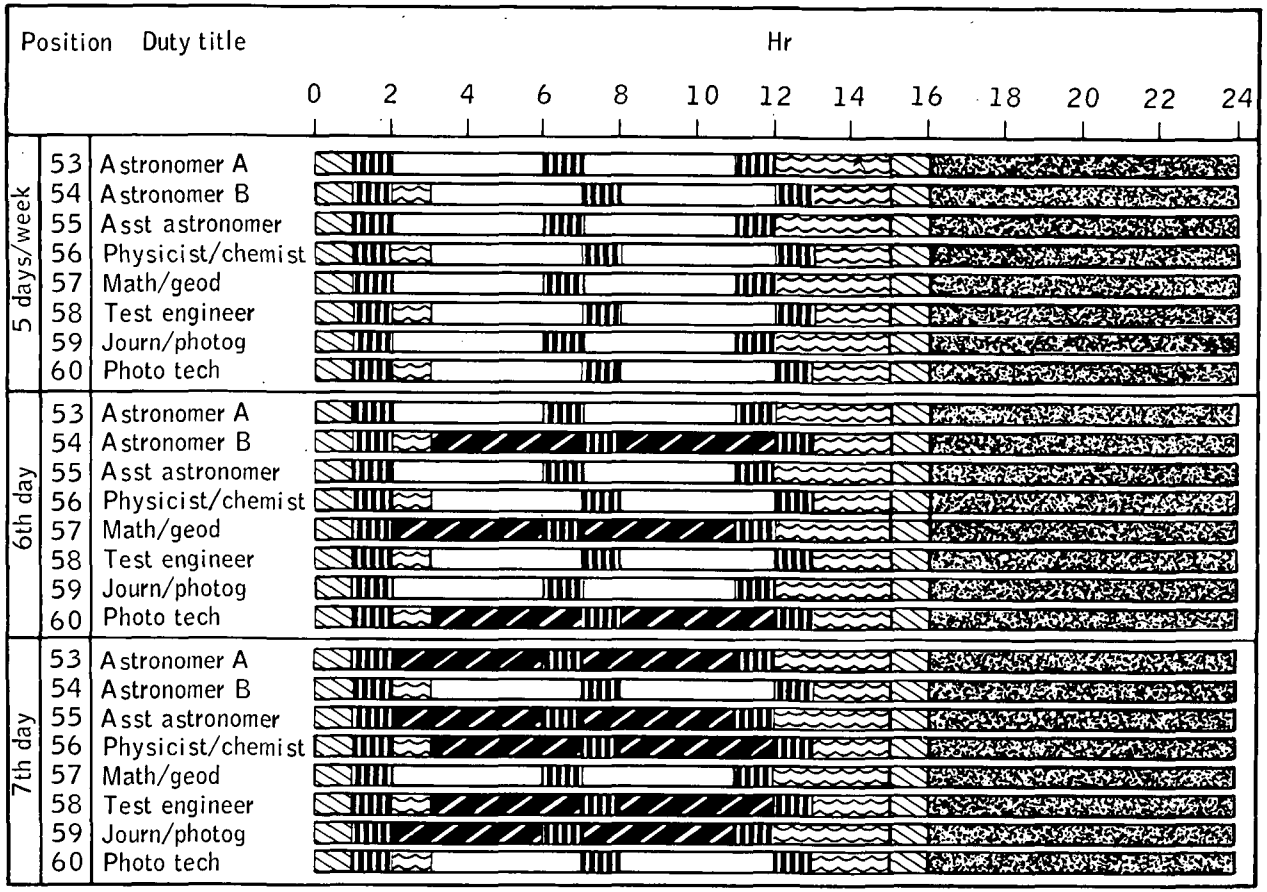
(b) Crew positions 40 to 47.

Figure 5. - Continued.



(c) Crew positions 48 to 52.

Figure 5.- Continued.



(d) Crew positions 53 to 60.

Figure 5.- Concluded.

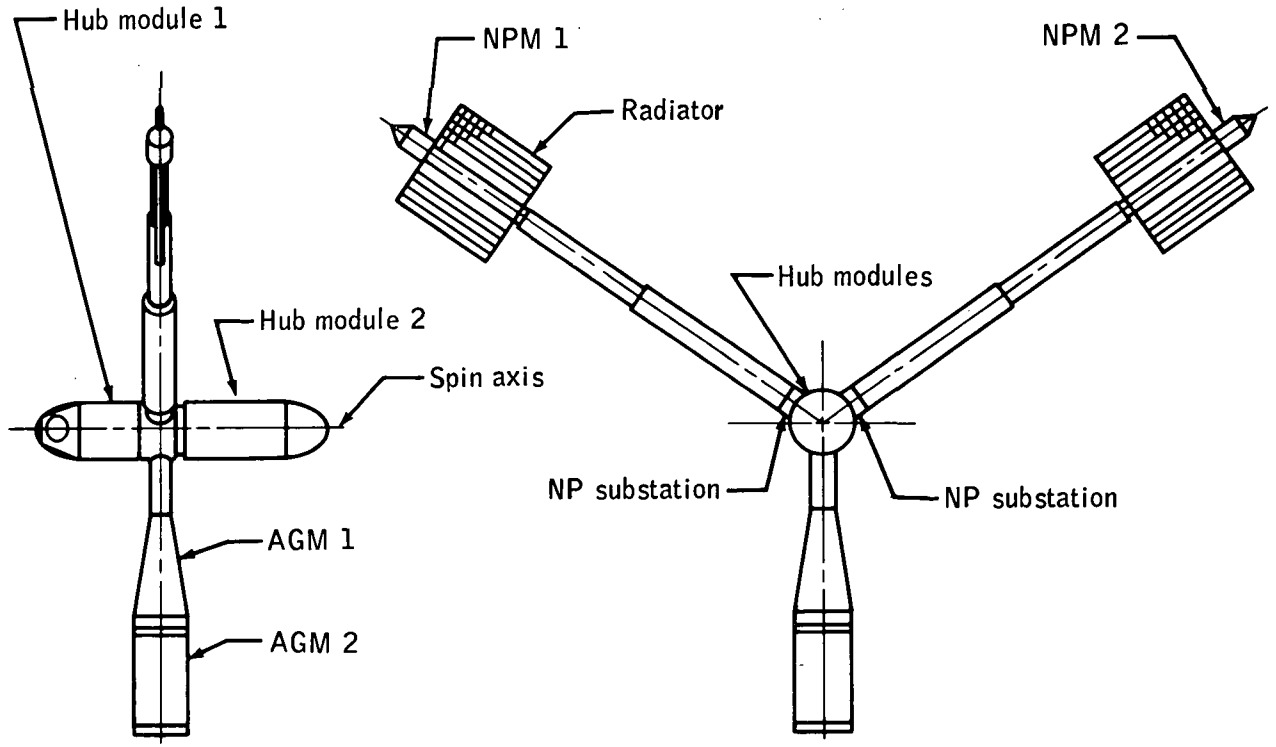


Figure 6. - Space-base general arrangement.

APPENDIX

CREW SKILLS AND WORK RESPONSIBILITIES

This appendix contains a detailed list (table XVI) of 106 crew positions in terms of station duties, major skills, special skills, work responsibilities, and the number of task categories per crewman. The list reflects the general philosophy contained in reference 4, in which a space base is visualized "to be large enough to provide accommodation for a crew possessing necessary skills for expert conduct of experiments as well as for more conventional spacecraft functions."

For instance, man's role as a scientist in space astronomy observatories is limited because it is largely an automatic, man-tended laboratory; but man should be available to maintain, repair, and replace faulty subsystems. He should be able to update, modify, and replace subsystems; to aline and calibrate instruments; to deploy the initial structure; and to operate instruments as a scientist-astronaut.

As in astronomy, man can contribute to the earth sciences and applications program by performing repairs, calibrations, alterations, and maintenance. He can assure the quality of the data and extend the useful lifetime of sensors. This is an autonomous space base, and man must function as scientific operator/controller/programer. A scientific specialist is also required for earth and space surveillance. In the applications area, man is utilized in the developmental phases of new instruments and in the proof of feasibility of measurement technique.

The role of man in the life sciences includes four categories: aerospace medicine, biotechnology, space biology, and exobiology. Aerospace medicine is concerned with the study of man's vulnerabilities in the space environment and management of disabilities. The biotechnology program relates to man as a scientist and operator to determine the capabilities and limitations of man to perform useful tasks in space. Man's role in space biology will be enhanced by his ability to carry out on-the-spot manipulative tasks and judgments.

Approximately 50 percent of the crew is required for the more conventional, operational spacecraft functions in a supporting role to the scientific community on board and the related experiment program. Man's operational role involves maintaining effective communications, maintenance, operation of the control center, navigation, piloting, systems monitoring, and logistics control.

Table XVI outlines the possible crew skills required for the experiment program and the operational aspects of the space base. The crew positions are listed in the first column. The crew-skills column indicates the crewman's prime responsibility and denotes any special skills required. The work responsibility column does not necessarily reflect the number of task categories; it is only by analyzing the position and related responsibilities that one is able to derive the correct number of tasks. In some cases, a large workload is indicated; but in the logical space-base crew buildup, as the size of the crew increases, the individual crew workload and versatility decreases.

TABLE XVI. - CREW SKILLS

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
1	Commander EOSB command and control Station management Comm. and navigation Spacecraft comm. DMS	Electrical engineer	Navigator Communicator	6
2	Deputy commander EOSB command and control (asst.) Biomed. testing (as subject) Safety	Chemical engineer	Biomed. sci. Behavioral sci. Biochemist	6
3	Biomed.-biotech. program mgr. (flight surgeon) Crew medical treatment Medical monitoring Biomed./behavioral studies Dental care	Surgeon	Physician Biotechnologist Physiologist Psychologist Biomedical sci.	7
4	Power systems officer Power-plant systems Preparation and operation of NP systems Fuel cells and EPS	Nuclear physicist	Chemist	4
5	Systems manager Subsystems monitoring and maintenance Computation Data analysis	Systems engineer	Instrumentation engineer	6
6	Technical director (chief scientist) Experiments and technology	Physical scientist (Ph. D.)	Biochemist	4
7	Operations and logistics manager Operations Logistics	General engineer	Operations analyst Supply specialist	5
8	Operations engineer A Monitoring and control of systems	Electronics engineer	Instrumentation engineer Test engineer	2
9	Operations engineer B Monitoring and control of systems	Electromechanical engineer	None	2
10	Astronomy observatory mgr. (experiment specialist) Astronomy (stellar, solar, and radio) Photographic experiments Optical experiments	Optical physicist (Ph. D.)	Astronomer Photographer Optical tech.	6
11	Communications officer Communications Data management	Electronics engineer	Instrument engineer Programer	2
12	DMS officer Data reduction, analysis, storage, and transmission	Electrical engineer	Computer programer	2

TABLE XVI. - CREW SKILLS - Continued

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
13	Systems management supervisor Scheduled and unscheduled maintenance of subsystems Onboard checkout Detection and fault isolation	Maintenance engineer	Electro-mechanical engineer	3
14	First Cook Meal scheduling, preparation, and serving Menu food supply	Chef	Nutritionist	5
15	Supply group manager Station experiment planning and scheduling Time and motion studies Manpower scheduling	Management analyst	Administrative weight engr. Mathematician	2
16	Test engineer Test programs, test reporting system Space mfg. processing Experiment and shop tests	Mechanical engineer	Electrical engineer	4
17	Experiment specialist Terrain mapping	Cartographer	Topographer	2
18	Experiment specialist Astronomy (stellar, solar, and radio) Photographic experiments Optical experiments	Astronomer	Photographer Optical tech.	4
19	Experiment specialist Animal care Bioscience experiments	Zoologist	Microbiologist Lab tech. Physiologist	5
20	Bioscience office mgr./experiment specialist Bioscience experiments	Biologist	Lab tech. Microscopist	7
21	Experiment specialist Bioscience experiments	Microbiologist	Lab tech.	7
22	Experiment specialist Bioscience experiments Biotech. experiments	Biochemist	Biotechnologist	6
23	Experiment specialist Earth surveillance (shape and size of the surface of the earth)	Geodesist	Mathematician	2
24	Experiment specialist Weather observation Earth resources experiments	Meteorologist	None	3
25	Operations office mgr. Manufacturing processes Test operations Maint. and repair experiments	Chemist	Physicist	6

TABLE XVI. - CREW SKILLS - Continued

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
26	Experiment specialist Earth and water surveillance (pollution control, mapping, etc.)	Oceanographer	None	3
27	Guidance and control officer Space navigation Docking operations Attitude and altitude control	Astronaut/engineer	Mathematician	2
28	Assistant astronomer Astronomy (stellar, solar, and radio) Photographic and optical experiments	Astronomer	Photographer Optical tech.	4
29	Biomed. scientist Medical experiment program Personal counseling	Medical doctor	Behavioral scientist	6
30	Electronics technician Scheduled and unscheduled maintenance	Maintenance and repair spec.	Testing technician	2
31	Computer programer DMS	Mathematician	Computer specialist	2
32	Metallurgist Advanced technology manufacturing processes Maintenance and repair test programs	Welding engineer	Test engr.	3
33	Machinist Machine and general shop equipment operation Welding and mfg. processes	Welder technician	Maintenance and repair spec.	3
34	Systems housekeeping supervisor Subsystems servicing Maintenance and repair	Electromechanical technician	Maintenance, service, and repair spec.	3
35	Physical therapist Exercise, recreation Physical therapy, massage	Physical education	Recreation supervisor	4
36	Navigator Space navigation Docking operations Attitude and altitude control	Astronaut	Aerospace technologist	2
37	Logistics specialist Station logistics Stockroom, crew, supplies, etc.	Storekeeper	Supply spec.	2
38	Experiment investigator Biomedicine and bioscience Behavioral science (human and animal)	Neurologist	None	4
39	Experiment investigator Bioscience/biomedicine	Physiologist	None	2

TABLE XVI. - CREW SKILLS - Continued

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
40	Traffic control observer Aircraft traffic control Earth and space surveillance	Flight operations engineer	Aeronautical engineer	2
41	Systems monitor/controller Control panel operation Caution and warning monitoring Communication	Instrument engineer	None	3
42	Data processing analyst DMS (data dump control and scheduling and programing)	Mathematician	None	3
43	Assistant navigator Space navigation Docking operations Attitude and altitude control	Astronaut/engineer	Electrical engineer	2
44	Officers' mess attendant Food serving Cleanup Cargo handling Communicator	Waiter	Cargo handler Phone talker (intercom) KP duty	3
45	Officers' steward Room and washroom cleanup Barber	Steward	Barber Damage and fire control party member	3
46	Medical technician Sick bay and biomed. lab Biomed. testing (as subject)	Lab Tech. (X-ray, etc.) Anesthesiologist	Med. tech.	3
47	Biotechnologist Preventive medicine Biotechnology experiments program Flight hardware evaluation	Medical doctor	Biochemist	2
48	Lab technologist Bioscience experiments Lab duties, microscopy Biology lab assistance	Biologist	Lab tech.	6
49	Lab technologist Biotechnology experiments Lab duties Biochemical assistance	Biochemist	None	6
50	Public affairs officer History and documentation Mission photography News and TV programing Photo. lab management	Journalist	Photographer	5
51	Control console operator Systems monitoring and control Space and ground communication	Electrical engineer	Systems engineer	2

TABLE XVI. - CREW SKILLS - *Continued*

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
52	Instrument technician Inst. shop machining Electromechanics Instr. operating Maintenance and repair of experiment instruments Instr. modifications, testing, and calibration	Machinist	Electromech. technician	3
53	Second cook Meal scheduling, preparation, serving, and cleanup Menu planning Food supply	Chef	Nutritionist	5
54	Cafeteria mess attendant Food serving in crew cafeteria Cargo handling Phone talker	Waiter	Cargo handler Phone talker	3
55	Officers' steward Room and washroom cleanup	Steward	Damage and fire control party member	3
56	Experiment specialist Microbiologist assistance Bioscience and medical experiments (lab tech.)	Microbiologist	Lab. tech.	4
57	Experiment investigator Oceanographic assistance Ocean surveillance Earth resources experiments (water sources, pollution, etc.)	Oceanographer	Marine biologist Physical scientist	4
58	Experiment investigator Experiments related to earth life and history	Geodesist	Geochemist	2
59	Experiment technologist Earth surveillance Geodesic assistance	Geodesist	Mathematician	2
60	Chemical technician Overall experiments program (chemical and instrument methods of analysis) Chemical lab assistance	Instr. test technician	Chemical analyst	4
61	Communications specialist Service and repair of communications equipment Comm. equipment experiments (antenna, radar, laser, TV, and tracking relay systems)	Electronics technician	Instrument technician	3

TABLE XVI. - CREW SKILLS - Continued

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
62	Optical technician Astronomical and other optical experiments Optical lab bench, maintenance, repair, test, checkout, calibration, adjustment	Instrument technician	None	3
63	Experiment asst. (bioscience) Animal care and feeding Experiment lab assistance	Veterinarian (D. V. M.)	Animal attendant	2
64	Mechanical technician Maintenance and repair of subsystems Modifications, testing Winch operation Logistics and supply	Rigger	Winch engineer	2
65	Chaplain Weekly nondenominational services Counseling Mental health monitoring Behavioral science	Minister or priest	Psychiatrist	5
66	Photographic technician Camera repair and modification for numerous support and experiment camera systems	Instrument machinist	Camera repairman	2
67	Experiment technician (mapping) Earth resources experiments (earth survey, maps, topography, map and chart making, terrain mapping of Zone of Interior and global areas)	Topographer	Surveyor	4
68	Experiment technician (meteorology) Earth resources experiment lab (weather observation and forecasting)	Meteorologist	Weather forecaster	3
69	Fabricator/assembler Maintenance and repair Machine shop equipment Fabrication and operation assembly Test setup	Machinist	Sheetmetal worker	4
70	Photo. lab technician Supply, collection and processing of film Light setup TV maintenance	Lighting specialist	Film processor	3
71	Operations research analyst Station experiment planning Time and motion studies Optimization of procedures and systems	Mathematician	Programer	4

TABLE XVI. - CREW SKILLS - Continued

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
72	Materials and metallurgy lab assistant Space mfg. lab Advanced tech. lab Maintenance and repair	General Machinist	Welder	3
73	Third cook Meal scheduling, diet control, meal serving, cleanup, menu planning	Chef	Dietician	5
74	Management technician Management directives, typing, clerical, technical writing	Operations flight clerk	Typist	4
75	Food management specialist Preparation, cleanup, supply, distribution Menu planning and meal scheduling	Nutrionist	None	5
76	Psychiatrist Crew mental health, stress level, efficiency, and energy monitoring Biomed. dept. and sick bay Sleeping and dreaming behavior records	Psychologist	Psychophysiologist	5
77	Pharmacist Sick bay and biomedical dept.	Pharmacist	Biomedical technician	2
78	Earth surveillance monitor Star field tracking with telescope (stellar, solar, and radio) Film processing	Photographer	None	3
79	Space surveillance monitor Star field tracking with telescope (stellar, solar, and radio) Film processing	Photographer	None	5
80	Laboratory technician General experiment lab duties, microscopy, etc.	Lab tech.	Microscopist	5
81	Control console monitor Station systems monitoring Onboard checkout and data display monitoring Space and ground communications	Astronaut/engineer	Systems engineer	2
82	Control console operator Systems monitoring and control in station command center	Systems engineer	None	2
83	Safety and damage control officer Station safety procedures Damage control party	General engineer	Safety specialist	2

TABLE XVI. - CREW SKILLS - Continued

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
84	Engineering officer Operation, maintenance, and repair of reactor and electrical installation Damage repair	Maintenance engineer	None	4
85	Maintenance and repair specialist Station maintenance inspection and repair	Maintenance technician	Painter	4
86	Electromechanical technician Maintenance and repair (experiments, subsystems, modifications, testing, calibration)	Electronics	Mech. tech.	2
87	Loadmaster Loading and unloading on station by logistic supply vehicles	Transportation engr.	Rigger/winch engr. Cargo handler	2
88	Supply specialist Supervision of general supplies Control of spare parts	Supply officer	Storekeeper	2
89	Agronomist Earth resources observation Station greenhouse maintenance	Agriculture specialist	Forestry specialist	4
90	Photographic specialist Photographic support Still and TV cameras Experiments	Photographer	Director	2
91	Operations engineer Orbital maneuvering and docking Sensor operation and evaluation Drill and security	Astronaut	Aerospace technologist	4
92	Welder Space mfg. lab welding Advanced technology lab welding Maint. and repair	Welder	Casting spec.	3
93	Storekeeper Station store Supply room	Supply specialist	Storeman	2
94	Dental surgeon Preventive dentistry, extraction, surgery, teeth cleaning, X-ray	Dentist	Oral hygienist	4
95	Hydrologist Earth resources observation (experiment, planning, target-of-opportunity observation)	Hydrologist	None	2
96	Materials engineer Implement space mfg. processes Blending materials Casting techniques Maintenance and repair	General engineer	Welding	3

TABLE XVI. - CREW SKILLS - Concluded

Crew position	Crewman and work responsibility	Crew skills		Major task categories
		Primary	Special	
97	Photographic technologist Mission photography assistance and documentation Photo. lab duty	Photographer	Illustrator	2
98	Test operations technician Test setup, operation of instruments, adjustment, calibration, recording, failure reports	Instrument technician	Electronics technician	2
99	EVA specialist/test subject Planning and execution of all EVA maneuvers Damage control duty	Astronaut/engineer	Damage control specialist	4
100	Photographic lab spec. Photo. lab duty (collection and processing of film, photography)	Photographer	Film processor	2
101	Weights engineer Continuous weight and balance control of the entire space base and its logistic changes	General engineer	Mathematician	2
102	Habitability specialist Work/sleep-cycle; food-consumption; clothing-usage; garbage-collection; light-, noise-, and vibration-level; and traffic-counter-readout monitoring	Architect	Engineer	4
103	Animal attendant Care and feeding of animals and plant life Lab assistance	Zookeeper	None	3
104	Male nurse Sick bay Surgery assistance Biomed. duties	Nurse (R.N.)	Lab. tech.	3
105	Anesthesiologist Sick bay, surgery room, lab tests, X-ray Biomed. duties	Medical doctor	Med. technologist	3
106	Janitor Overall cleaning of space base	Janitor	Custodian	6

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